



IOC Research Centre
for Prevention of Injury and Protection of Athlete Health

YISSEM
YONSEI INSTITUTE OF SPORTS SCIENCE & EXERCISE MEDICINE



2026 평창국제스노우스포츠안전학회 ISSS 2026 PYEONGCHANG

26th International Congress on
Snowsports Trauma & Safety

March 8th to 13th, 2026, PyeongChang, Republic of Korea

TOPICS

- Epidemiology
- Sports biomechanics
- Snow sports medicine and trauma management
- Mechanism of injury and prevention
- Rehabilitation and return-to-sport protocols
- Equipment safety and performance
- Ski area management & race safety
- Human science for snow sports safety



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President's Welcome Message

On behalf of the President of the Korean Orthopedic Sports Medicine Society, we extend our sincere congratulations on the International Society for Snowsports Safety 2026.

Especially, it is a great honor for the Korean Orthopaedic Sports Medicine Society (KOSSM) to participate as a co-host of ISSS 2026, to be held in PyeongChang, Korea.

As the President of KOSSM, I am pleased to support this international meeting, which brings together experts dedicated to improving safety, injury prevention, and clinical outcomes in snowsports. PyeongChang, with its strong legacy in winter sports, provides an ideal venue for meaningful academic exchange in this field.

The Medical Day program highlights the essential role of medical science, clinical expertise, and interdisciplinary collaboration in advancing injury prevention and athlete care in snowsports as well.

Through ISSS 2026, we look forward to strengthening international collaboration and sharing clinical and scientific insights across disciplines. KOSSM is committed to contributing its expertise in orthopaedic sports medicine and to supporting productive dialogue that advances snowsports safety and athlete care worldwide.

I sincerely hope that ISSS 2026 will be a rewarding and memorable experience for all participants, and I warmly welcome you to PyeongChang.

Jin-Hwan Kim, MD, PhD

President, Korean Orthopaedic Sports Medicine Society (KOSSM)

Chair's Welcome Message

Welcome to the 26th International Congress on Snowsports Trauma & Safety (ISSS 2026 PyeongChang).

It is my great honor and privilege to welcome all of you to PyeongChang, Korea, for this extraordinary gathering of experts, innovators, and leaders in the field of snowsports medicine, trauma management, and safety research. Hosting this prestigious congress—now celebrating more than 70 years of history—marks a meaningful moment for our scientific community and for the future of global snowsports safety.

This year's congress brings together medical professionals, sports scientists, engineers, industry partners, legal specialists, and ski resort leaders from around the world. Across the next several days, we will exchange insights, present new scientific evidence, explore emerging technologies, and strengthen global collaborations aimed at improving safety and performance for all who enjoy snow sports.

PyeongChang, with its legacy as a host of the Winter Olympic Games and its world-class winter-sports environment, provides an ideal setting for these discussions. I hope you take the time not only to participate in the scientific sessions but also to experience the unique culture, landscape, and hospitality that Korea has to offer.

I extend my sincere appreciation to all speakers, presenters, committee members, and volunteers whose dedication and hard work made this congress possible. Most importantly, I thank each of you for your commitment to advancing our shared mission of enhancing safety in snowsports worldwide.

I wish you a productive, inspiring, and memorable week here in PyeongChang.

With warm regards,

Congress Chair, ISSS 2026 PyeongChang

DooSup Kim, MD PhD



26th International Congress on
Snowsports Trauma & Safety



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- Young-Hee Lee , M.D., Ph.D. *Professor Emeritus, Yonsei University, KOREA*

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International

- Pierre-Jean Arnoux Ph.D.(President) *Faculté des Sciences Médicales et Paramédicales
Marseille Université / Université Gustave Eiffel, Marseille, FRANCE*
- Irving Scher Ph.D., P.E. (Chairman) *Guidance Engineering and Applied Research, Seattle,
Washington, USA*
- Viet Senner Ph.D. *School of Engineering and Design, Technical University of Munich, GERMANY*
- Tom Allen Ph.D. *Sports Engineering, Manchester Metropolitan University, Routledge Research in
Sports and Technology and Engineering, UNITED KINGDOM*
- Rick Greenwald Ph.D. *Simbex, New Hampshire, USA*

CONTENT

Day 1 Sun, Mar 8

16:00 – 18:00	Registration	
18:00 – 20:00	Opening / Grand Ballroom	
	Opening : 5min	<i>SeungPyo Eun</i>
	Welcome address : 5min	<i>DooSup Kim / Jin-Whan Kim</i>
	Presidential lecture : 20min	<i>Pierr-jean Arnoux</i>
	Performance & Dinner : 30min	
End of Day 1		

Day 2 Mon, Mar 9

08:30 – 08:40	Opening Opening and welcome address	<i>DooSup Kim (YISSEM Director)</i>
08:40 – 09:40	Keynote Keynote lecture	<i>Chair : Pierr-jean Arnoux</i>
	Pioneering Ski Safety : The Sugarbush Project: Bob Johnson, Carl Ettingler, Jake Shealy Contributions to IIS, ASTM & ISO Standards : 40min	<i>Jasper Shealy</i>
	Legacy as Responsibility: The Enduring Impact of Carl Ettliger : 15min	<i>Heidi Ettliger</i>
09:40 – 10:55	Free Paper Epidemiology	<i>Chair : Lars Engebretsen</i>

	2022-2023 NSAA 10-Year Interval Injury Study: Skiing and Snowboarding Injuries in the United States: 15min	<i>Lenka Stepan</i>
	Evidence Across Three Decades: The Current State of Skiing and Snowboarding Injuries in Switzerland : 15min	<i>Flavia Bürgi</i>
	Injury epidemiology and Treatment/Prevention strategies for ski/snowboarding participants in Taiwan : 15min	<i>Yi-Chiang Yang</i>
	Epidemiological Analysis of Knee Injuries in Skiing and Snowboarding A sixteen years' experience in Greece : 15min	<i>Nikolas Bourganos</i>
	National Monitoring of Mountain Biking Injuries in Switzerland : 15min	<i>Lynn Ellenberger</i>
10:55 – 11:15	Break Coffee Break	
11:15 – 12:30	Free Paper Physiology	<i>Chair : Matej Supej</i>
	Medical and surgical issues during the Winter Olympic Games: 15min	<i>Lars Engebretsen</i>
	Heart Rhythm monitoring with the wearable ECG during the endurance sports in athletes : 15min	<i>Yoo Ri Kim</i>
	Snowsports benefits for active healthy aging : 15min	<i>Tracey Dickson</i>
	The Overlooked Side of Snowsports: How Inadequate Nutrition and Hydration Affect Young Skiers and Snowboarders. : 15min	<i>Evangelia Koutra</i>
	Cardiopulmonary Exercise Responses to Uphill Treadmill Testing in Elite Iranian Sky Running and Ski Athletes : 15min / Video	<i>Haleh Dadgostar</i>
12:30 – 14:00	Break Lunch	
14:00 – 14:30	Keynote Keynote lecture	<i>Chair : Irving Scher</i>
	history of skiing and snowboarding injury research around the world over since 1950 with an emphasis on using peer-reviewed literature. : 30 min	<i>Rick Greenwald</i>

14:30 – 15:30	Free Paper Equipment : Binding etc.	<i>Chair : Irving Scher</i>
	Performance of Children’s Alpine Ski Bindings using ASTM F504 : 15min	<i>Garrett Porter</i>
	The effect of carbon shin pads on ski boot stiffness : 15min	<i>Michael Hasler</i>
	Numerical Evaluation of a Back Protector in Critical Skiing and Mountain Biking Falls : 15min	<i>Guillaume Olgiati</i>
	Analysis of Binding Release Setting Patterns in Youth Alpine Ski Racing : 15min	<i>David O’Sullivan</i>
15:30 – 15:50	Break Coffee Break	
15:50 – 16:50	Free Paper Biomechanics 1	<i>Chair : David O’Sullivan</i>
	From Video to Joint Kinematics: A Markerless Workflow for Skiing Injury Analysis : 15min	<i>Michael Zwölfer</i>
	An IMU Motion Capture System for Snowboarding Based on Biomechanical Constraint Optimization : 15min	<i>Wenze Wu</i>
	Extracting Biomechanically Meaningful Patterns for Skiing Motion: Decomposition and Clustering of 4-DoF Unilateral Lower-Limb Modes : 15min	<i>Yuke Hu</i>
	Investigating dry ski–snow friction : 15min	<i>Shiraz Ahmed Siddiqui</i>
End of Day 2		

Day 3 Tue, Mar 10

06:00 – 07:30	Event SkiMo : Red/Gold paradise (Bring your own SkiMo and headlight!)	<i>Captain : Changhyu Choi</i>
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09:00 – 09:40	Keynote Keynote lecture 40min	<i>Chair : DooSup Kim</i>
	The IOC strategy to handle injuries and illnesses in the Olympic Games : 40min	<i>Lars Engebretsen</i>
09:40 – 10:40	Free Paper Biomechanics / Engineering	<i>Chair : Rick Greenwald</i>
	Characterizing ambulation potential following acute traumatic spinal cord injury: a populational cohort study on 1209 patients : 15min	<i>Philippe Phan</i>
	Landing Location Variation Due to Jump Geometry : 15min	<i>Christopher Pedrotti</i>
	Landing Location Variation Due to Pop Speed Variation : 15min	<i>Christopher Pedrotti</i>
	Biomechanical analysis of knee ligament loading during ski jump landing : 15min	<i>Wei Wei</i>
10:40 – 11:00	Break Coffee Break	
11:00 – 12:00	Free Paper Biomechanics 2	<i>Chair : Lenka Stepan</i>
	Pole Length Modulates Cycle and Ground Contact Time During Simulated Uphill Ski Mountaineering: 15min	<i>Matej Supej</i>
	COMPENSATORY MOTOR STRATEGIES AND CHANGES IN MUSCLE ACTIVITY DURING PROLONGED ALPINE SKIING: A FIELD-BASED SINGLE SUBJECT CASE STUDY : 15min	<i>Aron Ra</i>
	Functional Adaptation of Knee Extensors to Chronic Eccentric Loading: A Key Protective Mechanism Against High-Force Injury in Alpine Skiing : 15min	<i>Tae-Gyu Han</i>
	Association Between Tibial Torsion, ACL Injury, and Functional Biomechanics in Elite Alpine Skiers : 15min	<i>Sae Young Park</i>
12:00 – 13:30	Break Lunch	
13:30 – 13:50	Keynote Keynote lecture	<i>Chair : Irving Scher</i>
	50 year study of Fatalities in Snowsports	<i>Jasper Shealy</i>

13:30 – 14:35	Free Paper Helmet	<i>Chair : Tracy Dickson</i>
	Rethinking Helmet Design in Snowsports: The Role of Fit, Compliance, and Human Factors in Reducing Head Injury Risk : 15min	<i>Rob Joseph</i>
	Head Accelerations during Falls in Snowboard Halfpipe – A Case Study in Comparison to a Comprehensive Reference Dataset : 15min	<i>Uwe G. Kersting</i>
	Comparing Snowsport Helmet Impact Performance : 15min	<i>Nicole Stark</i>
14:35 – 15:20	Round table “The future of snow sport safety and ISSS in a changing environment” : 45min	<i>Chair : Tom Allen</i>
	Flavia Bürgi (BFU - Swiss Council for Accident Prevention) Tracey Dickson (University of Canberra) Matej Supej (University of Ljubljana) Lenka Stepan (Guidance Engineering and Applied Research) Michael Zwölfer (Universität Innsbruck)	
15:20 – 15:40	Break Coffee Break	
15:40 – 17:25	Free Paper ski area safety	<i>Chair : Flavia Burgi</i>
	Ski Area Padding: Examining the Potential to Mitigate Injury Risk at Beginner Speeds : 15min	<i>Irving Scher</i>
	Pilot Study on the Effectiveness of Deceleration Nets for Falls from Chairlift : 15min	<i>Alexander Horst</i>
	SPORSA: Safety and Tracking Platform for Mountain Sports : 15min	<i>Robbe Decorte</i>
	A Four-Step Pressure-Based Sliding Turn Teaching Algorithm for Hard-Snow Slopes in Korea : 15min	<i>Jee-Hyeok Im</i>
	The Influence of Environmental and Human Factors on Inbounds Skiing Accidents at a Representative Alpine Resort in Western North America : 15min	<i>Duncan Knight</i>

	RECYCLE OF END-OF-LIFE SAFETY EQUIPMENT FOR SKI RESORTS : 15min	<i>Martino Colonna</i>
	Considering inclusive sporting goods for snow sport safety: 15min	<i>Tom Allen</i>
18:00- 20:00	Event Korean Chi-maek Party (YongPyong Wine Bar, Dragon Valley Hotel)	
End of Day 3		

Day 4 Wed, Mar 11

10:00 – 12:00	Ski race	Mega green slope
12:00 – 14:00	Lunch	YongPyong Wine bar
End of Day 4		

Day 5 Thu, Mar 12

06:00 – 07:30	Event SkiMo : Red/Gold paradise (Bring your own SkiMo and headlight!)	<i>Captain : Changhyu Choi (Gachon University)</i>
08:00 – 08:25	Registration	
08:25 – 08:30	Opening Opening and welcome address	<i>Jin Hwan Kim (KOSSM president / Inje University)</i>
08:30 – 09:20	Keynote Keynote lecture	<i>Chairman : Jin-Hwan Kim (Inje University), Sang-Hak Lee (Kyunghee University)</i>
	Sports medicine, past, present and future. : 25min	<i>Hideo Matsumoto (Keio)</i>

		<i>University)</i>
	Multiligament injuries, diagnoses, treatment and results among high level skiers : 25min	<i>Lars Engebretsen (Oslo University Hospital)</i>
09:20 – 10:00	Free paper Epidemiology	<i>Chairman: Hideyuki Koga (Institute of Science Tokyo), Nam-Hong Choi (Eulji University)</i>
	Injury Patterns Before and During Competition Among Korean National Winter Sport Athletes : 6min	<i>RyuKyoung Cho (Gachon University)</i>
	Epidemiological Analysis of Wrist and Forearm Injuries in Skiing and Snowboarding A sixteen years' experience in Greece : 10min	<i>Athanasios Zacharopoulos (General Hospital of Amfissa)</i>
	Descriptive epidemiology of symptomatic femoroacetabular impingement in young athlete: Single center study : 6min	<i>Jung-Mo Hwang (Chungnam University)</i>
	Orthopaedic sports injury in adult elite ice hockey players in South Korea : 6min	<i>Kanghun Yu (Korea University)</i>
	Discussion : 12min	
10:00 – 10:20	Break Coffee Break	
10:20 – 11:10	Symphosium Pathomechanism and prevention of Ski and Snowboard injuries	<i>Chairman : Jong-Hun Ji (Catholic University), Hyuk-Soo Han (Seoul National University)</i>
	Shoulder: Shoulder Instability and Clavicle Fracture: Pathomechanism of Slope Trauma and Equipment-Based Prevention : 10min	<i>Chaegwan Kong (Catholic University)</i>
	Knee: Biomechanics of the ACL Injury in the Ski : 10min	<i>Moon Jong Chang (Boramae Medical Center)</i>
	Ankle: Snowboarder's Fracture: Pathomechanism and Prevention Strategies : 10min	<i>Seung-Myung Choi (Daejeon Bone Hospital)</i>
	Spine: Overuse Pathomechanics of Lumbar Disc and Pars Injuries in Skiers/Snowboarders : 10min	<i>Hyung-Rae Lee (Korea University)</i>

	Discussion : 10min	
11:10 – 11:50	Free paper Upper extremity and spinal injuries	<i>Chairman : Jung-Han Kim (Inje University)</i>
	Rotator cuff injury and Alpine Ski : 6min	<i>Su-Cheol Kim (Samsung medical center)</i>
	High Rates of Return to Sport After Arthroscopic Shoulder Stabilization in Elite Winter Sports Athletes : 6min	<i>Jae-Sung Park (Neon Orthopaedic Clinic)</i>
	Clavicle Fractures in recreational Skiing and snowboarding : Mechanism of injury and injury pattern : 6min	<i>Myung-Rae Kim (Kyunghee University)</i>
	Epidemiology and injury patterns of traumatic shoulder dislocation in Skiing and Snowboarding: a multicenter tertiary hospital-based study in Korea : 6min	<i>Yeong-Hwan Jang (Wonju severance hosp.)</i>
	Winter-Sports-Related Spine Injuries in a Limited-Snowfall Setting: Epidemiology and Injury Patterns from A Cross-Sectional Survey in South Korea : 6min	<i>Hong Jin Kim (Korea univ.)</i>
	Discussion : 10min	
11:50 – 13:00	Break Lunch	
13:00 – 13:25	Keynote Keynote lecture	<i>Chairman : Hideo Matsumoto (Keio University), Bernat Alegret (Medicina Esportiva)</i>
	Preventive measures for ACL injury based on its mechanisms in FIS World Cup alpine skiing : 25min	<i>Hideyuki Koga (Institute of Science Tokyo)</i>
13:25 – 14:05	Free paper Mechanisms of ACL injury	<i>Chairman : Werner Nachbauer (University of Innsbruck)</i>
	MRI- and Arthroscopy-Based Comparative Analysis of Concomitant Injury Patterns in Non-Contact ACL Injuries: Skiing versus Soccer : 6min	<i>Geunwu Gimm (Seoul National University)</i>

	Concomitant Knee Pathology and Remnant Quality in Ski- versus Soccer-Related ACL Injuries – A Propensity Score Matched Cohort Study : 6min	<i>Joon-Ho Wang (Sungkyunkwan University)</i>
	A New Mechanism of ACL Injury in Skiing - New Phantom Foot Mechanism : 6min	<i>SeungPyo Eun (Korea Orthopedic Clinic)</i>
	Anatomic risk factors associated with ACL injury in ski and soccer injury : 6min	<i>Sang-Hak Lee (Kyunghee University)</i>
	Femoral Morphological Characteristics Predisposing to Anterior Cruciate Ligament Rupture in Skiing Injuries: A Three-Dimensional Statistical Shape Analysis : 6min	<i>Sung-Hwan Kim (Yonsei University)</i>
	Discussion : 10min	
14:05 – 14:55	Symphosium Common lower extremity injuries : Diagnosis and treatment	<i>Chairman : SeungPyo Eun (Korea Orthopedic Clinic), Joon-Ho Wang (Sungkyunkwan University)</i>
	Knee: ACL tears in Skiing and Snowboarding : 10min	<i>Sang-Hak Lee (Kyunghee University)</i>
	Knee: Concomittant ligament (ACL + PCL, PLI , MCL and meniscus) injury in Skiing : 10min	<i>Du-Han Kim (Kyemyung University)</i>
	Foot and ankle : Common ski/snowboard injuries in foot and ankle: diagnosis and management : 10min	<i>Jae-Hwang Song (Konyang University)</i>
	Hip : Femoroacetabular impingement and labral tear: Diagnosis and management : 10min	<i>Suk-Kyoon Song (Daegu Catholic University)</i>
	Discussion : 10min	
14:55 – 15:15	Break Coffee break	
15:15 – 15:50	Free paper Common upper extremity injuries	<i>Chairman : Woong-Kyu Jeong (Korea University), Su-Cheol Kim (Samsung medical center)</i>
	Comparison of around elbow injury pattern between Skiing and Snowboarding : 6min	<i>Jung-Han Kim (Inje University)</i>
	The role of Hand dominance in traumatic shoulder	<i>Hyung-Jin Chung (Chung-</i>

	injuries during winter sports: A comparative analysis of fractures, dislocations, and rotator cuff tears : 6min	<i>nam University)</i>
	Clinical characteristics and treatment outcomes of proximal humerus fractures in winter sports: Comparison between skiing and snowboarding injuries : 6min	<i>Hyung-Seok Park (Chosun University)</i>
	Association of Warm-up, Safety-Checking Behaviors, and Training Habits with 12-Month Spine Injury in Winter Sports Athletes: A Cross-Sectional Surve : 6min	<i>Hyung-Rae Lee (Korea University)</i>
	Discussion : 11min	
15:50 – 16:40	Symposium Upper extremity and spinal injuries	<i>Chairman : Joo Yop Lee (Catholic University), Chaegwan Kong (Catholic University)</i>
	Shoulder : Distinctions in the Diagnosis and Management of Snow Sports Injuries Versus Non-Sports-Related Trauma. : 10min	<i>Jae Soo Kim (Chung-Ang University)</i>
	Elbow : High-Velocity Rotatory Instability of the Elbow: Differentiation from General Instability and Associated Therapeutic Strategies : 10min	<i>Jun-Gyu Moon (Korea University)</i>
	Hand /Wrist : Common wrist injuries in winter sports : from diagnosis to treatment : 10min	<i>Hyoung-Seok Jung (Chung-Ang University)</i>
	Spline: Lumbosacral Pain in Skiers and Snowboarders: Differential Diagnosis and Management : 10min -	<i>Ki Youn Kwon (Wonju Severance Christian Hospital)</i>
	Discussion : 10min	
<i>End of Day 5</i>		

Day 6 Fri, Mar 13

08:00 – 08:25	Keynote Keynote lecture	<i>Chairman : Nam-Hong Choi</i>
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		<i>(Eulji University), Hideyuki Koga (Institute of Science Tokyo)</i>
	Treatment for ACL injury in snow sports : 25min	<i>Joon Ho Wang (Samsung Medical Center)</i>
08:25 – 09:30	Free paper Knee and upper extremity injury	<i>Chariman : Choongsoo Shin(Seogang University), Sung-Hwan Kim (Yonsei University)</i>
	ACL reconstruction to control the pivot shift while restricting normal tibial rotation : 10min	<i>Hideo Matsumoto (Keio University)</i>
	Treatment strategies for ACL injuries -ACL reconstruction alone is not enough : 10min	<i>Hideyuki Koga (Institute of Science Tokyo)</i>
	Medial-to-Lateral Hamstring Muscle Balance and Frontal-Plane Knee Loading: Implications for ACL Injury Prevention in Female Skiers and Snowboarders : 6min	<i>Jinkyu Lee Korea (National Rehabilitation Center)</i>
	Age-specific Patterns of Concomitant Bone Contusions and Meniscal Tears in Skiing-Related Anterior Cruciate Ligament Injuries : 6min	<i>Geunwu Gimm (Seoul National University)</i>
	Elite vs. Non-elite Skiers: Distinct Meniscal and Osseous Injury Patterns in ACL Rupture : 6min	<i>Geunwu Gimm (Seoul National University)</i>
	Hand and Wrist Injuries: Common Patterns and Treatment Strategies : 6min	<i>Duke Chung (Micro hospital)</i>
	Correlation between Ski pole use and humeral shaft fracture : 6min	<i>Hyojune Kim (Chung-Ang University)</i>
	Discussion : 15min	
09:30 – 10:20	Symphosium Future safety and medical technologies in Skiing and Snowboarding	<i>Chairman : Dong-Hwi Kim(Chosun University), Sang-Hak Lee (Kyunghee University)</i>
	Evaluation of AI-based musculoskeletal disease and	<i>Eun Ji Yoon (Orthocare,</i>

	clinical prediction of digital treatment systems : 10min	<i>Catholic University</i>
	Intelligent Orthopedics: The Next Wave of Musculoskeletal AI : 10min	<i>Du Hyun Ro (CONNECTEVE, Seoul National University)</i>
	Robotic rehabilitation with digitalized therapeutic hand, no more uncertain prompt: 'Future Physical AI" : 10min	<i>Jun Yeul Lim (MEDISBY, Yonsei University)</i>
	Personalized rehabilitation to everyone : 10min	<i>Chan Yoon (Ever Ex)</i>
	Discussion : 10min	
10:20 – 10:40	Break Coffee Break	
10:40 – 11:40	Case discussion Case discussion with panel	<i>Chairman :Yong In(Catholic University), Jun-Gyu Moon (Korea University)</i>
	Upper extremity : Clinical Decision-Making for Common Upper Extremity Trauma (My treatment strategy according to patients specific condition) : 30min	<i>Jung-Han Kim (Inje University)</i>
	Hyung-Jin Chung (Chung nam univ.), Jun-Hyuk Lim (Chonnam National Univ.), Tae-Hwan Yoon (Severance hosp.), Su-Cheol Kim (Samsung Medical Center)	
	Lower extremity : knee injury in snowsports : 30min	<i>Min Jung (Yunsei University)</i>
	Hyuk-Soo Han (Seoul univ.), Dong-Hwi Kim (Chosun univ.), Sung-Hwan Kim (Yonsei univ.)	
11:40 – 12:40	Break Lunch	
12:40 – 13:00	Keynote Keynote lecture (15min + 5min discussion)	<i>Chairman : Duke Chung (Micro Hospital), Jong-Hun Ji (Catholic University)</i>
	Shoulder dislocation and bony Bankart lesions in winter sports athletes : 20min	<i>Jin-Young Park (Neon Orthopaedic Clinic)</i>
13:00 – 13:50	Symposium Rehabilitation and Return to sports after Ski and	<i>Chairman : Jin-Hwan Kim (Inje University), Sung Hyun</i>

	Snowboard injuries	<i>Lee (CHA University)</i>
	Upper extremity: "Stronger Shoulders, Safer Hands": Restoring Dynamic Stability and Power: Rehabilitation Training for Upper Extremity Injuries in Skiers and Snowboarders : 10min	<i>Myung-Seo Kim (Kyunghee University)</i>
	Knee : Aggressive rehabilitation is better in acute ACL tear of skiing ? : 10min	<i>Ki Bong Park (Ulsan University)</i>
	Ankle: Functional Rehabilitation for Syndesmotic and High Ankle Sprain in Skiers: Proprioception and Core Integration : 10min	<i>Gi Won Choi (Korea University)</i>
	Spine: Lumbar Disc Herniation in Skiers and Snowboarders: Evidence-Based Return-to-Snow (RTS) : 10min	<i>Byung-Ho Lee (Yonsei University)</i>
	Discussion : 10min	
13:00 – 14:00 Banquet Hall (2 nd Floor)	Case discussion Case discussion with pannel	
	Upper extremity : Functional Recovery of Common Upper Extremity Injuries (My rehabilitation strategy and decision to RTS) : 30min	<i>Chairman : Woong Kyo Jeong (Korea University)</i>
	Young- Dae Jeon (Ulsan univ.), Young-Min Noh (Busan medical center), Jung-Young Kim (Daegu Catholic univ.)	
	Lower extremity: Functional Recovery of Common Lower Extremity Injuries (My rehabilitation strategy and decision to RTS) : 30min	<i>Chairman : Ki Bong Park (Ulsan University)</i>
	Min Jung (Yunsei univ.), SeungPyo Eun (Korea Orthopedic Clinic), Hyung-Seok Choi (Sunchyunghyang univ.), Du Hyun Ro (Seoul Nat'l Univ).	
14:00 – 14:20	Break Coffee Break	
14:20 – 15:10	Symposium Child and Adolescent injury in ski/snowboard	<i>Chairman :Hyung-Suk Choi (Soonchunhyang University), Hyuk-Soo Han</i>

		<i>(Seoul National University)</i>
	Shoulder and elbow: Safeguarding the Physis: Distinct Upper Extremity Injury Patterns and Modern Management in Young Skiers and Snowboarders. : 10min	<i>Woo-Yong Lee (Chungnam University)</i>
	Knee: Pediatric Knee and Lower-Leg Injuries in Ski and Snowboarding : 10min	<i>Chang-Ho Shin (Seoul National University)</i>
	hand : Understanding Skier's Thumb in Adolescent Athletes: Etiology, Diagnosis, and Management : 10min	<i>Jae woo Shim (Sungkyunkwan University)</i>
	Foot and Ankle: Physeal and Apophyseal Injuries in the Adolescent Foot and Ankle : 10min	<i>Ho-Won Kang (Seoul Star Hospital)</i>
	Discussion : 10min	
14:20 – 15:20 Banquet Hall (2 nd Floor)	Debate Debate : Pro vs Con	<i>Chairman : Joo Yop Lee(Catholic University), Woo-Yong Lee (Chungnam University)</i>
	Shoulder : AC CC injury : Hook vs. Button, Operative vs. conservative : 15min	<i>Hyungsuk Kim (Catholic University) vs. Su-Cheol Kim (Samsung Medical Center)</i>
	Shoulder : First time shoulder dislocation : Operative vs. conservative : 15min	<i>Hyung-Jin Chung (Chungnam University) vs. Jong-Pil Yoon (Kyungpook National University)</i>
	Foot & ankle Syndesmosis Injury in Snow Sports: Static Fixation vs. Dynamic Fixation : 15min	<i>Chul Hyun Park (Yeungnam University) vs. Sung-Hyun Lee (CHA University)</i>
	Early Return-to-Play Treatment for Symptomatic Lumbar Disc Herniation in Ski/Snowboard Athletes: Early Surgery vs. Injection Therapy : 15min	<i>Sang Soo Eun (Bumin Hospital) vs. Min-Seok Kang (Konkuk University)</i>
15:20 – 15:30	Closing remark : 10min	<i>Jin-Hwan Kim (Inje University)</i>

17:30 – 22:00	Event Gala Dinner (Grand Ballroom)	
End of Day 6 : Adjournment		

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**BOOK OF
ABSTRACT**

March 8th to 13th, 2026, PyeongChang, Republic of Korea



IOC Research Centre
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ISSS2026 PYEONGCHANG

26th International Congress on Snowsports Trauma & Safety

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BOOK OF ABSTRACT

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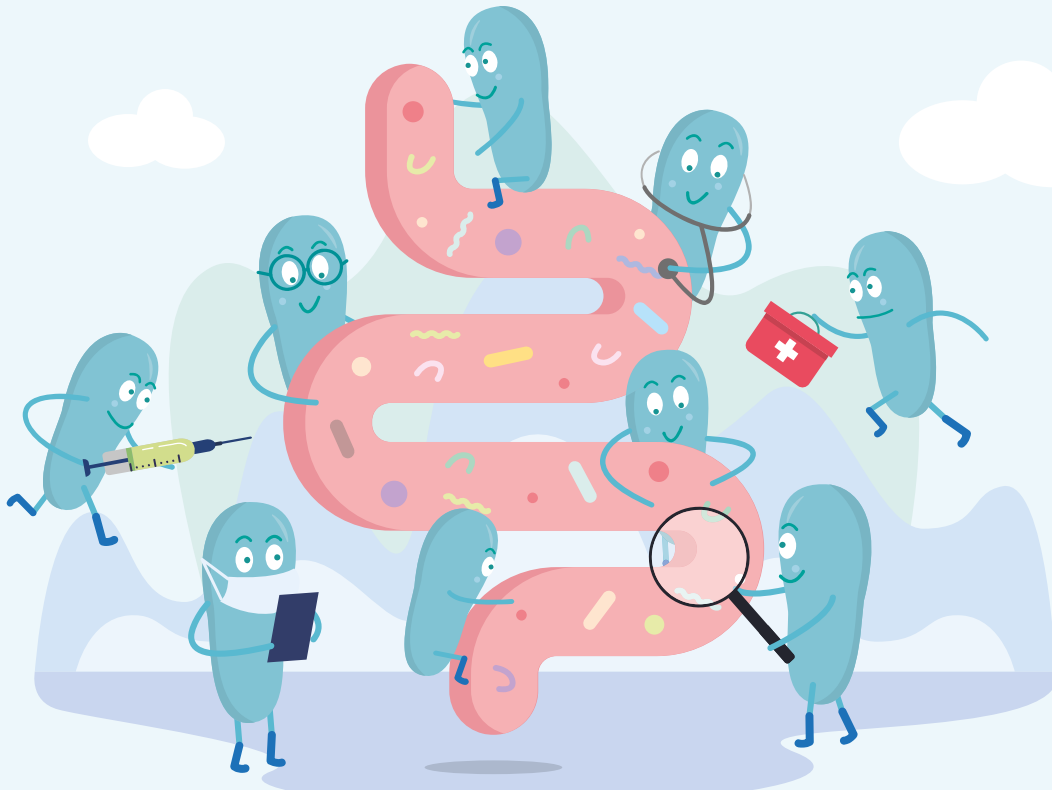


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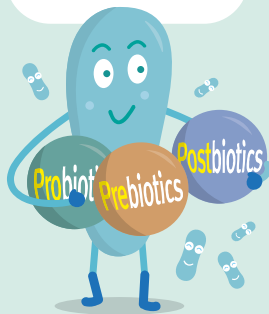


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*** According to VAS pain intensity, Pain Intensity Differences and Pain Relief scores. Dosed as one vial every 6 hours over 48 hour period.¹

References : 1. Daniels, S.E, Playne, R., Stanescu, I., Zhang, J., Gottlieb, L.J, Atkinson, H.C. (2019). Efficacy and safety of an intravenous acetaminophen/ibuprofen fixed-dose combination after bunionectomy: A randomized, double-blind, factorial, placebo-controlled trial. Clinical Therapeutics <https://doi.org/10.1016/j.clinthera.2019.07.008>. Research sponsored by AFT Pharmaceuticals.

CONTENT

Day 1 Sun, Mar 8

16:00 – 18:00	Registration	
18:00 – 20:00	Opening / Grand Ballroom	
	Opening : 5min	<i>SeungPyo Eun</i>
	Welcome address : 5min	<i>DooSup Kim / Jin-Whan Kim</i>
	Presidential lecture : 20min	<i>Pierr-jean Arnoux</i>
	Performance & Dinner : 30min	
End of Day 1		

Day 2 Mon, Mar 9

08:30 – 08:40	Opening Opening and welcome address	<i>DooSup Kim (YISSEM Director)</i>
08:40 – 09:40	Keynote Keynote lecture	<i>Chair : Pierr-jean Arnoux</i>
	Pioneering Ski Safety : The Sugarbush Project: Bob Johnson, Carl Ettingler, Jake Shealy Contributions to IIS, ASTM & ISO Standards : 40min	<i>Jasper Shealy</i>
	Legacy as Responsibility: The Enduring Impact of Carl Ettliger : 15min	<i>Heidi Ettliger</i>
09:40 – 10:55	Free Paper Epidemiology	<i>Chair : Lars Engebretsen</i>

	2022-2023 NSAA 10-Year Interval Injury Study: Skiing and Snowboarding Injuries in the United States: 15min	<i>Lenka Stepan</i>
	Evidence Across Three Decades: The Current State of Skiing and Snowboarding Injuries in Switzerland : 15min	<i>Flavia Bürgi</i>
	Injury epidemiology and Treatment/Prevention strategies for ski/snowboarding participants in Taiwan : 15min	<i>Yi-Chiang Yang</i>
	Epidemiological Analysis of Knee Injuries in Skiing and Snowboarding A sixteen years' experience in Greece : 15min	<i>Nikolas Bourganos</i>
	National Monitoring of Mountain Biking Injuries in Switzerland : 15min	<i>Lynn Ellenberger</i>
10:55 – 11:15	Break Coffee Break	
11:15 – 12:30	Free Paper Physiology	<i>Chair : Matej Supej</i>
	Medical and surgical issues during the Winter Olympic Games: 15min	<i>Lars Engebretsen</i>
	Heart Rhythm monitoring with the wearable ECG during the endurance sports in athletes : 15min	<i>Yoo Ri Kim</i>
	Snowsports benefits for active healthy aging : 15min	<i>Tracey Dickson</i>
	The Overlooked Side of Snowsports: How Inadequate Nutrition and Hydration Affect Young Skiers and Snowboarders. : 15min	<i>Evangelia Koutra</i>
	Cardiopulmonary Exercise Responses to Uphill Treadmill Testing in Elite Iranian Sky Running and Ski Athletes : 15min / Video	<i>Haleh Dadgostar</i>
12:30 – 14:00	Break Lunch	
14:00 – 14:30	Keynote Keynote lecture	<i>Chair : Irving Scher</i>
	history of skiing and snowboarding injury research around the world over since 1950 with an emphasis on using peer-reviewed literature. : 30 min	<i>Rick Greenwald</i>

14:30 – 15:30	Free Paper Equipment : Binding etc.	<i>Chair : Irving Scher</i>
	Performance of Children’s Alpine Ski Bindings using ASTM F504 : 15min	<i>Garrett Porter</i>
	The effect of carbon shin pads on ski boot stiffness : 15min	<i>Michael Hasler</i>
	Numerical Evaluation of a Back Protector in Critical Skiing and Mountain Biking Falls : 15min	<i>Guillaume Olgiati</i>
	Analysis of Binding Release Setting Patterns in Youth Alpine Ski Racing : 15min	<i>David O’Sullivan</i>
15:30 – 15:50	Break Coffee Break	
15:50 – 16:50	Free Paper Biomechanics 1	<i>Chair : David O’Sullivan</i>
	From Video to Joint Kinematics: A Markerless Workflow for Skiing Injury Analysis : 15min	<i>Michael Zwölfer</i>
	An IMU Motion Capture System for Snowboarding Based on Biomechanical Constraint Optimization : 15min	<i>Wenze Wu</i>
	Extracting Biomechanically Meaningful Patterns for Skiing Motion: Decomposition and Clustering of 4-DoF Unilateral Lower-Limb Modes : 15min	<i>Yuke Hu</i>
	Investigating dry ski–snow friction : 15min	<i>Shiraz Ahmed Siddiqui</i>
End of Day 2		

Day 3 Tue, Mar 10

06:00 – 07:30	Event SkiMo : Red/Gold paradise (Bring your own SkiMo and headlight!)	<i>Captain : Changhyu Choi</i>
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09:00 – 09:40	Keynote Keynote lecture 40min	<i>Chair : DooSup Kim</i>
	The IOC strategy to handle injuries and illnesses in the Olympic Games : 40min	<i>Lars Engebretsen</i>
09:40 – 10:40	Free Paper Biomechanics / Engineering	<i>Chair : Rick Greenwald</i>
	Characterizing ambulation potential following acute traumatic spinal cord injury: a populational cohort study on 1209 patients : 15min	<i>Philippe Phan</i>
	Landing Location Variation Due to Jump Geometry : 15min	<i>Christopher Pedrotti</i>
	Landing Location Variation Due to Pop Speed Variation : 15min	<i>Christopher Pedrotti</i>
	Biomechanical analysis of knee ligament loading during ski jump landing : 15min	<i>Wei Wei</i>
10:40 – 11:00	Break Coffee Break	
11:00 – 12:00	Free Paper Biomechanics 2	<i>Chair : Lenka Stepan</i>
	Pole Length Modulates Cycle and Ground Contact Time During Simulated Uphill Ski Mountaineering: 15min	<i>Matej Supej</i>
	COMPENSATORY MOTOR STRATEGIES AND CHANGES IN MUSCLE ACTIVITY DURING PROLONGED ALPINE SKIING: A FIELD-BASED SINGLE SUBJECT CASE STUDY : 15min	<i>Aron Ra</i>
	Functional Adaptation of Knee Extensors to Chronic Eccentric Loading: A Key Protective Mechanism Against High-Force Injury in Alpine Skiing : 15min	<i>Tae-Gyu Han</i>
	Association Between Tibial Torsion, ACL Injury, and Functional Biomechanics in Elite Alpine Skiers : 15min	<i>Sae Young Park</i>
12:00 – 13:30	Break Lunch	
13:30 – 13:50	Keynote Keynote lecture	<i>Chair : Irving Scher</i>
	50 year study of Fatalities in Snowsports	<i>Jasper Shealy</i>

13:30 – 14:35	Free Paper Helmet	<i>Chair : Tracy Dickson</i>
	Rethinking Helmet Design in Snowsports: The Role of Fit, Compliance, and Human Factors in Reducing Head Injury Risk : 15min	<i>Rob Joseph</i>
	Head Accelerations during Falls in Snowboard Halfpipe – A Case Study in Comparison to a Comprehensive Reference Dataset : 15min	<i>Uwe G. Kersting</i>
	Comparing Snowsport Helmet Impact Performance : 15min	<i>Nicole Stark</i>
14:35 – 15:20	Round table “The future of snow sport safety and ISSS in a changing environment” : 45min	<i>Chair : Tom Allen</i>
	Flavia Bürgi (BFU - Swiss Council for Accident Prevention) Tracey Dickson (University of Canberra) Matej Supej (University of Ljubljana) Lenka Stepan (Guidance Engineering and Applied Research) Michael Zwölfer (Universität Innsbruck)	
15:20 – 15:40	Break Coffee Break	
15:40 – 17:25	Free Paper ski area safety	<i>Chair : Flavia Burgi</i>
	Ski Area Padding: Examining the Potential to Mitigate Injury Risk at Beginner Speeds : 15min	<i>Irving Scher</i>
	Pilot Study on the Effectiveness of Deceleration Nets for Falls from Chairlift : 15min	<i>Alexander Horst</i>
	SPORSA: Safety and Tracking Platform for Mountain Sports : 15min	<i>Robbe Decorte</i>
	A Four-Step Pressure-Based Sliding Turn Teaching Algorithm for Hard-Snow Slopes in Korea : 15min	<i>Jee-Hyeok Im</i>
	RECYCLE OF END-OF-LIFE SAFETY EQUIPMENT FOR SKI RESORTS : 15min	<i>Martino Colonna</i>
	Considering inclusive sporting goods for snow sport	<i>Tom Allen</i>

	safety: 15min	
18:00- 20:00	Event Korean Chi-maek Party (YongPyong Wine Bar, Dragon Valley Hotel)	
End of Day 3		

Day 4 Wed, Mar 11

10:00 – 12:00	Ski race	Mega green slope
12:00 – 14:00	Lunch	YongPyong Wine bar
End of Day 4		

Day 5 Thu, Mar 12

06:00 – 07:30	Event SkiMo : Red/Gold paradise (Bring your own SkiMo and headlight!)	<i>Captain : Changhyu Choi (Gachon University)</i>
08:00 – 08:25	Registration	
08:25 – 08:30	Opening Opening and welcome address	<i>Jin Hwan Kim (KOSSM president / Inje University)</i>
08:30 – 09:20	Keynote Keynote lecture	<i>Chairman : Jin-Hwan Kim (Inje University), Sang-Hak Lee (Kyunghee University)</i>
	Sports medicine, past, present and future. : 25min	<i>Hideo Matsumoto (Keio University)</i>
	Multiligament injuries, diagnoses, treatment and	<i>Lars Engebretsen (Oslo</i>

	results among high level skiers : 25min	<i>University Hospital)</i>
09:20 – 10:00	Free paper Epidemiology	<i>Chairman: Hideyuki Koga (Institute of Science Tokyo), Nam-Hong Choi (Eulji University)</i>
	Injury Patterns Before and During Competition Among Korean National Winter Sport Athletes : 6min	<i>RyuKyoung Cho (Gachon University)</i>
	Epidemiological Analysis of Wrist and Forearm Injuries in Skiing and Snowboarding A sixteen years' experience in Greece : 10min	<i>Athanasios Zacharopoulos (General Hospital of Amfissa)</i>
	Descriptive epidemiology of symptomatic femoroacetabular impingement in young athlete: Single center study : 6min	<i>Jung-Mo Hwang (Chungnam University)</i>
	Orthopaedic sports injury in adult elite ice hockey players in South Korea : 6min	<i>Kanghun Yu (Korea University)</i>
	Discussion : 12min	
10:00 – 10:20	Break Coffee Break	
10:20 – 11:10	Symposium Pathomechanism and prevention of Ski and Snowboard injuries	<i>Chairman : Jong-Hun Ji (Catholic University), Hyuk-Soo Han (Seoul National University)</i>
	Shoulder: Shoulder Instability and Clavicle Fracture: Pathomechanism of Slope Trauma and Equipment-Based Prevention : 10min	<i>Chaegwan Kong (Catholic University)</i>
	Knee: Biomechanics of the ACL Injury in the Ski : 10min	<i>Moon Jong Chang (Boramae Medical Center)</i>
	Ankle: Snowboarder's Fracture: Pathomechanism and Prevention Strategies : 10min	<i>Seung-Myung Choi (Daejeon Bone Hospital)</i>
	Spine: Overuse Pathomechanics of Lumbar Disc and Pars Injuries in Skiers/Snowboarders : 10min	<i>Hyung-Rae Lee (Korea University)</i>
	Discussion : 10min	

11:10 – 11: 50	Free paper Upper extremity and spinal injuries	<i>Chairman : Jung-Han Kim (Inje University)</i>
	Rotator cuff injury and Alpine Ski : 6min	<i>Su-Cheol Kim (Samsung medical center)</i>
	High Rates of Return to Sport After Arthroscopic Shoulder Stabilization in Elite Winter Sports Athletes : 6min	<i>Jae-Sung Park (Neon Orthopaedic Clinic)</i>
	Clavicle Fractures in recreational Skiing and snowboarding : Mechanism of injury and injury pattern : 6min	<i>Myung-Rae Kim (Kyunghee University)</i>
	Epidemiology and injury patterns of traumatic shoulder dislocation in Skiing and Snowboarding: a multicenter tertiary hospital-based study in Korea : 6min	<i>Yeong-Hwan Jang (Wonju severance hosp.)</i>
	Winter-Sports-Related Spine Injuries in a Limited- Snowfall Setting: Epidemiology and Injury Patterns from A Cross-Sectional Survey in South Korea : 6min	<i>Hong Jin Kim (Korea univ.)</i>
	Discussion : 10min	
11:50 – 13:00	Break Lunch	
13:00 – 13:25	Keynote Keynote lecture	<i>Chairman : Hideo Matsumoto (Keio University), Bernat Alegret (Medicina Esportiva)</i>
	Preventive measures for ACL injury based on its mechanisms in FIS World Cup alpine skiing : 25min	<i>Hideyuki Koga (Institute of Science Tokyo)</i>
13:25 – 14:05	Free paper Mechanisms of ACL injury	<i>Chairman : Werner Nachbauer (University of Innsbruck)</i>
	MRI- and Arthroscopy-Based Comparative Analysis of Concomitant Injury Patterns in Non-Contact ACL Injuries: Skiing versus Soccer : 6min	<i>Geunwu Gimm (Seoul National University)</i>

	Concomitant Knee Pathology and Remnant Quality in Ski- versus Soccer-Related ACL Injuries – A Propensity Score Matched Cohort Study : 6min	<i>Joon-Ho Wang (Sungkyunkwan University)</i>
	A New Mechanism of ACL Injury in Skiing - New Phantom Foot Mechanism : 6min	<i>SeungPyo Eun (Korea Orthopedic Clinic)</i>
	Anatomic risk factors associated with ACL injury in ski and soccer injury : 6min	<i>Dong Hyun Klm (Kyunghee University)</i>
	Femoral Morphological Characteristics Predisposing to Anterior Cruciate Ligament Rupture in Skiing Injuries: A Three-Dimensional Statistical Shape Analysis : 6min	<i>Sung-Hwan Kim (Yonsei University)</i>
	Discussion : 10min	
14:05 – 14:55	Symphosium Common lower extremity injuries : Diagnosis and treatment	<i>Chairman : SeungPyo Eun (Korea Orthopedic Clinic), Joon-Ho Wang (Sungkyunkwan University)</i>
	Knee: ACL tears in Skiing and Snowboarding : 10min	<i>Sang-Hak Lee (Kyunghee University)</i>
	Knee: Concomittant ligament (ACL + PCL, PLI , MCL and meniscus) injury in Skiing : 10min	<i>Du-Han Kim (Kyemyung University)</i>
	Foot and ankle : Common ski/snowboard injuries in foot and ankle: diagnosis and management : 10min	<i>Jae-Hwang Song (Konyang University)</i>
	Hip : Femoroacetabular impingement and labral tear: Diagnosis and management : 10min	<i>Suk-Kyoon Song (Daegu Catholic University)</i>
	Discussion : 10min	
14:55 – 15:15	Break Coffee break	
15:15 – 15:50	Free paper Common upper extremity injuries	<i>Chairman : Woong-Kyu Jeong (Korea University), Su-Cheol Kim (Samsung medical center)</i>
	Comparison of around elbow injury pattern between Skiing and Snowboarding : 6min	<i>Jung-Han Kim (Inje University)</i>
	The role of Hand dominance in traumatic shoulder	<i>Hyung-Jin Chung (Chung-</i>

	injuries during winter sports: A comparative analysis of fractures, dislocations, and rotator cuff tears : 6min	<i>nam University)</i>
	Clinical characteristics and treatment outcomes of proximal humerus fractures in winter sports: Comparison between skiing and snowboarding injuries : 6min	<i>Hyung-Seok Park (Chosun University)</i>
	Association of Warm-up, Safety-Checking Behaviors, and Training Habits with 12-Month Spine Injury in Winter Sports Athletes: A Cross-Sectional Surve : 6min	<i>Hyung-Rae Lee (Korea University)</i>
	Discussion : 11min	
15:50 – 16:40	Symposium Upper extremity and spinal injuries	<i>Chairman : Joo Yop Lee (Catholic University), Chaegwan Kong (Catholic University)</i>
	Shoulder : Distinctions in the Diagnosis and Management of Snow Sports Injuries Versus Non-Sports-Related Trauma. : 10min	<i>Jae Soo Kim (Chung-Ang University)</i>
	Elbow : High-Velocity Rotatory Instability of the Elbow: Differentiation from General Instability and Associated Therapeutic Strategies : 10min	<i>Jun-Gyu Moon (Korea University)</i>
	Hand /Wrist : Common wrist injuries in winter sports : from diagnosis to treatment : 10min	<i>Hyoung-Seok Jung (Chung-Ang University)</i>
	Spline: Lumbosacral Pain in Skiers and Snowboarders: Differential Diagnosis and Management : 10min -	<i>Ki Youn Kwon (Wonju Severance Christian Hospital)</i>
	Discussion : 10min	
<i>End of Day 5</i>		

Day 6 Fri, Mar 13

08:00 – 08:25	Keynote Keynote lecture	<i>Chairman : Nam-Hong Choi</i>
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		<i>(Eulji University), Hideyuki Koga (Institute of Science Tokyo)</i>
	Treatment for ACL injury in snow sports : 25min	<i>Joon Ho Wang (Samsung Medical Center)</i>
08:25 – 09:30	Free paper Knee and upper extremity injury	<i>Chariman : Choongsoo Shin(Seogang University), Sung-Hwan Kim (Yonsei University)</i>
	ACL reconstruction to control the pivot shift while restricting normal tibial rotation : 10min	<i>Hideo Matsumoto (Keio University)</i>
	Treatment strategies for ACL injuries -ACL reconstruction alone is not enough : 10min	<i>Hideyuki Koga (Institute of Science Tokyo)</i>
	Medial-to-Lateral Hamstring Muscle Balance and Frontal-Plane Knee Loading: Implications for ACL Injury Prevention in Female Skiers and Snowboarders : 6min	<i>Jinkyu Lee Korea (National Rehabilitation Center)</i>
	Age-specific Patterns of Concomitant Bone Contusions and Meniscal Tears in Skiing-Related Anterior Cruciate Ligament Injuries : 6min	<i>Geunwu Gimm (Seoul National University)</i>
	Elite vs. Non-elite Skiers: Distinct Meniscal and Osseous Injury Patterns in ACL Rupture : 6min	<i>Geunwu Gimm (Seoul National University)</i>
	Hand and Wrist Injuries: Common Patterns and Treatment Strategies : 6min	<i>Duke Chung (Micro hospital)</i>
	Correlation between Ski pole use and humeral shaft fracture : 6min	<i>Hyojune Kim (Chung-Ang University)</i>
	Discussion : 15min	
09:30 – 10:20	Symphosium Future safety and medical technologies in Skiing and Snowboarding	<i>Chairman : Dong-Hwi Kim(Chosun University), Sang-Hak Lee (Kyunghee University)</i>
	Evaluation of AI-based musculoskeletal disease and	<i>Eun Ji Yoon (Orthocare,</i>

	clinical prediction of digital treatment systems : 10min	<i>Catholic University</i>
	Intelligent Orthopedics: The Next Wave of Musculoskeletal AI : 10min	<i>Du Hyun Ro (CONNECTEVE, Seoul National University)</i>
	Robotic rehabilitation with digitalized therapeutic hand, no more uncertain prompt: 'Future Physical AI" : 10min	<i>Joon Ryul Lim (MEDISBY, Yonsei University)</i>
	Personalized rehabilitation to everyone : 10min	<i>Chan Yoon (Ever Ex)</i>
	Discussion : 10min	
10:20 – 10:40	Break Coffee Break	
10:40 – 11:40	Case discussion Case discussion with panel	<i>Chairman :Yong In(Catholic University), Jun-Gyu Moon (Korea University)</i>
	Upper extremity : Clinical Decision-Making for Common Upper Extremity Trauma (My treatment strategy according to patients specific condition) : 30min	<i>Jung-Han Kim (Inje University)</i>
	Hyung-Jin Chung (Chung nam univ.), Jun-Hyuk Lim (Chonnam National Univ.), Tae-Hwan Yoon (Severance hosp.), Su-Cheol Kim (Samsung Medical Center)	
	Lower extremity : knee injury in snowsports : 30min	<i>Min Jung (Yunsei University)</i>
	Hyuk-Soo Han (Seoul univ.), Dong-Hwi Kim (Chosun univ.), Sung-Hwan Kim (Yonsei univ.)	
11:40 – 12:40	Break Lunch	
12:40 – 13:00	Keynote Keynote lecture (15min + 5min discussion)	<i>Chairman : Duke Chung (Micro Hospital), Jong-Hun Ji (Catholic University)</i>
	Shoulder dislocation and bony Bankart lesions in winter sports athletes : 20min	<i>Jin-Young Park (Neon Orthopaedic Clinic)</i>

	The Influence of Environmental and Human Factors on Inbounds Skiing Accidents at a Representative Alpine Resort in Western North America : 15min	<i>Duncan Knight</i>
13:00 – 13:50	Symposium Rehabilitation and Return to sports after Ski and Snowboard injuries	<i>Chairman : Jin-Hwan Kim (Inje University), Sung Hyun Lee (CHA University)</i>
	Knee : Aggressive rehabilitation is better in acute ACL tear of skiing ? : 10min	<i>Ki Bong Park (Ulsan University)</i>
	Upper extremity: "Stronger Shoulders, Safer Hands": Restoring Dynamic Stability and Power: Rehabilitation Training for Upper Extremity Injuries in Skiers and Snowboarders : 10min	<i>Myung-Seo Kim (Kyunghee University)</i>
	Ankle: Functional Rehabilitation for Syndesmotic and High Ankle Sprain in Skiers: Proprioception and Core Integration : 10min	<i>Gi Won Choi (Korea University)</i>
	Spine: Lumbar Disc Herniation in Skiers and Snowboarders: Evidence-Based Return-to-Snow (RTS) : 10min	<i>Byung-Ho Lee (Yonsei University)</i>
	Discussion : 10min	
13:00 – 14:00 Banquet Hall (2 nd Floor)	Case discussion Case discussion with pannel	
	Upper extremity : Functional Recovery of Common Upper Extremity Injuries (My rehabilitation strategy and decision to RTS) : 30min	<i>Chairman : Woong Kyo Jeong (Korea University)</i>
	Young- Dae Jeon (Ulsan univ.), Young-Min Noh (Busan medical center), Jun-Young Kim (Daegu Catholic univ.)	
	Lower extremity: Functional Recovery of Common Lower Extremity Injuries (My rehabilitation strategy and decision to RTS) : 30min	<i>Chairman : Ki Bong Park (Ulsan University)</i>
	Min Jung (Yunsei univ.), SeungPyo Eun (Korea Orthopedic Clinic), Hyung-Seok Choi (Sunchyunghyang univ.), Du Hyun Ro (Seoul Nat'l Univ).	

14:00 – 14:20	Break Coffee Break	
14:20 – 15:10	Symposium Child and Adolescent injury in ski/snowboard	<i>Chairman :Hyung-Suk Choi (Soonchunhyang University), Hyuk-Soo Han (Seoul National University)</i>
	Shoulder and elbow: Safeguarding the Physis: Distinct Upper Extremity Injury Patterns and Modern Management in Young Skiers and Snowboarders. : 10min	<i>Woo-Yong Lee (Chungnam University)</i>
	Knee: Pediatric Knee and Lower-Leg Injuries in Ski and Snowboarding : 10min	<i>Chang-Ho Shin (Seoul National University)</i>
	hand : Understanding Skier's Thumb in Adolescent Athletes: Etiology, Diagnosis, and Management : 10min	<i>Jae woo Shim (Sungkyunkwan University)</i>
	Foot and Ankle: Physeal and Apophyseal Injuries in the Adolescent Foot and Ankle : 10min	<i>Ho-Won Kang (Seoul Star Hospital)</i>
	Discussion : 10min	
14:20 – 15:20 Banquet Hall (2 nd Floor)	Debate Debate : Pro vs Con	<i>Chairman : Joo Yop Lee(Catholic University), Woo-Yong Lee (Chungnam University)</i>
	Shoulder : AC CC injury : Hook vs. Button, Operative vs. conservative : 15min	<i>Hyungsuk Kim (Catholic University) vs. Su-Cheol Kim (Samsung Medical Center)</i>
	Shoulder : First time shoulder dislocation : Operative vs. conservative : 15min	<i>Hyung-Jin Chung (Chungnam University) vs. Jong-Pil Yoon (Kyungpook National University)</i>
	Foot & ankle Syndesmosis Injury in Snow Sports: Static Fixation vs. Dynamic Fixation : 15min	<i>Chul Hyun Park (Yeungnam University) vs. Sung-Hyun Lee (CHA University)</i>

	Early Return-to-Play Treatment for Symptomatic Lumbar Disc Herniation in Ski/Snowboard Athletes: Early Surgery vs. Injection Therapy : 15min	<i>Sang Soo Eun (Bumin Hospital) vs. Min-Seok Kang (Konkuk University)</i>
15:20 – 15:30	Closing remark : 10min	<i>Jin-Hwan Kim (Inje University)</i>
17:30 – 22:00	Event Gala Dinner (Grand Ballroom)	
End of Day 6 : Adjournment		

2022-2023 NSAA 10-Year Interval Injury Study: Skiing and Snowboarding Injuries in the United States

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Keywords: Skiing, Snowboarding, Injury Incidence

INTRODUCTION. Every 10 years since 1980, the National Ski Areas Association (NSAA) has commissioned a study of ski patrol reports to better understand recreational skiing and snowboarding injuries and identify injury trends in the United States [1]. The current study examines ski patrol reports from the 2022-2023 season to determine injury rates, mechanisms, and risk factors for skiers and snowboarders.

METHODS. Ski patrol reports from the 2022-2023 winter season were obtained by NSAA from 32 US ski areas of various sizes and from all geographic regions. Reports were included if the patient was injured while skiing or snowboarding and excluded if the patient suffered a medical event, was working at the ski area, or actively racing at the time of injury. The data and narratives for each report were reviewed to categorize the type of incident and suspected injury. Demographic data (age, gender, ability, and whether the participant was a skier or snowboarder) were also extracted from each ski patrol report. Incident rates for skiers and snowboarders were calculated based on the daily skier visits for the participating ski areas and estimates of skier and snowboarder percentages, age, gender, and ability from the 2022-2023 NSAA Kottke End of Season & Demographic Report [2].

RESULTS. Out of the 20,754 ski patrol reports received, 18,980 met the inclusion criteria. The overall incident rate was 2.2 incidents per 1000 visits; skiers had a lower incident rate (1.7/1000 visits) compared to snowboarders (3.3/1000 visits). Beginners were significantly more likely to be injured than intermediates (OR=2.3, $p<0.001$) and advanced and expert participants (OR=5.5, $p<0.001$). Female skiers were more prone to injuries than their male counterparts (OR=1.23, $p<0.001$), while female snowboarders were less likely to be injured than males (OR=0.82, $p<0.001$). Snowsport participants in the 18- to 24-year-old age range had the highest incident rate of all age categories and were at least 2.5 times ($p<0.001$) more likely to be involved in an incident compared to younger and older skiers and snowboarders. Incidents were most frequently reported on trails designated as Easiest for snowboarders (35%) and More Difficult for skiers (41%). Falls due to loss of control were the most common cause of incidents (1.4/1000 visits), followed by the use of terrain features (0.28/1000 visits), collisions with other people (0.14/1000 visits), lift-related incidents (0.12/1000 visits), and collisions with objects (0.11/1000 visits). For skiers, the knee was the most injured body part (35%), while shoulder (23%) and wrist injuries (20%) were the most prevalent among snowboarders.

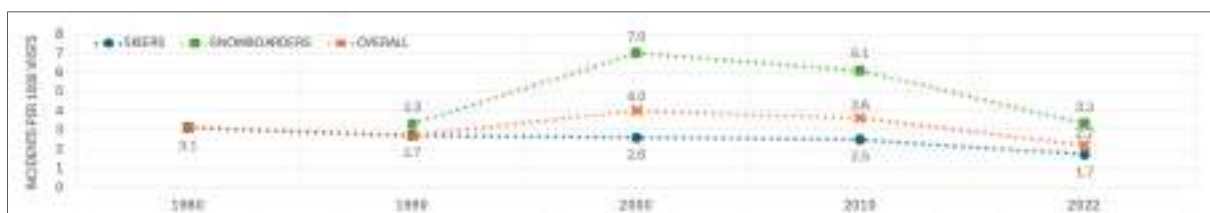


Figure 1. Injury incident rates for skiers and snowboarders at US ski areas from 1980 to 2022.

DISCUSSION. The current study evaluated incidents from 32 ski areas representing 13% of the total visits to US ski areas in the 2022/2023 season. Overall, the incident rate for snow sport participants declined 39% from 2010/2011 to 2.2 incidents per 1000 visits in 2022/2023; the incident rate decreased by 32% for skiers and 46% for snowboarders, see Figure 1. Similar to the previous 2010/2011 study [1], snowboarders and beginners had higher incidents rates compared to skiers and more experienced participants, and most incidents were a result of a fall from a loss of control and/or technical error (64%).

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Evidence Across Three Decades: The Current State of Skiing and Snowboarding Injuries in Switzerland

Flavia Bürgi^{1*}, Lynn Ellenberger¹ & Delphine Meier¹

¹ *BFU, Swiss Council for Accident Prevention, Switzerland*

Keywords: skiing, snowboarding, injury prevention, accident data, monitoring

INTRODUCTION. Skiing and snowboarding are among the most popular winter sports in Switzerland. However, on average more than 66,000 skiers and snowboarders sustain injuries that require medical attention each year in Swiss ski resorts [1]. Consequently, the snow sport injury prevention has long been a priority of the BFU, Swiss Council for Accident Prevention. To support evidence-based prevention, the BFU has established a comprehensive injury monitoring system combining several complementary data sources. This study summarizes the current injury situation in Swiss snow sports and highlights relevant key patterns for prevention.

METHODS. The injury monitoring comprises three data sources: (1) The BFU extrapolation model provides national estimates of the overall injury burden in Switzerland, based on a standardized population survey and accident records from mandatory accident insurers, [2]. (2) Fatal incidents have been systematically documented since 2000 within the BFU Statistics on Fatal Sports Accidents, a full survey drawing on multiple independent data sources and conducted in collaboration with external partners [3]. (3) Detailed information on injury mechanisms and circumstances is obtained from the ski patrol database, which covers around 20% of all ski and snowboard injuries. Ski patrollers record standardized data on demographics, accident location, and injury type and severity using an online reporting tool [4]. The injury risk was calculated using skier-days counted in Switzerland.

RESULTS. Of the approximately 66,000 individuals injured annually while skiing or snowboarding in Switzerland 12,000 are foreign visitors. While about 80% of all accidents result in minor injuries, roughly 4,000 individuals per year sustain severe injuries and 17 fatal incidents occur. Eleven of these fatalities happen off-piste during freeriding and six on marked slopes; touring accidents are not included. The overall injury rate on Swiss slopes is approximately 3 skiers or snowboarders per 1,000 skier-days. On average collisions accounted for only 8% of the on-slope accidents treated by ski patrols, yet they were associated with a disproportionately high risk of severe injury. Among skiers, knee injuries were most prevalent (39%), whereas snowboarders most frequently sustained injuries to the lower arm and hand (33%) and to the shoulder and upper arm (26%). Head injuries accounted for 10% of skiing injuries and 12% of snowboarding injuries; notably, 64% of these were moderate or severe.

DISCUSSION. The overall number and the risk of ski- and snowboard-related injuries in Switzerland have remained stable for decades, despite factors such as higher speeds and evolving user behavior that could have increased risk. This stability indicates that existing prevention measures effectively counterbalance these developments.

CONCLUSIONS. Although injury risk has been maintained at a stable level, the number of severe injuries remains high. Additional efforts from all involved stakeholders are needed to further reduce severe ski and snowboard injuries in Switzerland.

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Topic: Injury epidemiology and Treatment/Prevention strategies for ski/snowboarding participants in Taiwan

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Purpose: To identify injury patterns among Taiwanese snow-sports participants—a population that exclusively travels abroad for skiing and snowboarding due to local climate conditions—and to analyze current trends in treatment and prevention strategies within the Taiwanese healthcare system.

Methods: Data were collected throughout 2025 via surveys administered during 20+ injury prevention seminars and clinical intakes at a tertiary hospital in Taipei. The study assessed demographics, riding experience, injury mechanisms, and treatment history. This serves as the primary epidemiological dataset for this specific demographic.

Results: The study identified the knee (48.9%) as the primary injury site for snowboarders, followed by the shoulder and elbow (11.1% each). High-risk mechanisms identified include freestyle park riding, tree runs, ground tricks, and falls on icy terrain. A discrepancy in care pathways was noted: while most patients initially seek orthopedic consultation, the nature of these injuries often necessitates physiatric intervention.

Conclusion: The injury profile of Taiwanese snow-sports enthusiasts reflects specific high-risk behaviors associated with overseas travel and "thrill-seeking" in limited timeframes. There is a notable paradigm shift in management, with patients increasingly seeking regenerative treatments (e.g., prolotherapy, ESWT) and functional rehabilitation. These findings suggest a need for improved pre-trip prevention education and streamlined referral pathways between orthopedics and physical and rehabilitation medicine (PRM) in Taiwan.

Epidemiological Analysis of Knee Injuries in Skiing and Snowboarding

A sixteen years' experience in Greece

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Keywords: knee, ski, snowboard, injuries, epidemiology

INTRODUCTION. Knee injuries have consistently been among the most common injuries in Snowsports worldwide, imposing a considerable clinical and operational burden on athletes and healthcare services. Certain athlete groups appear to be at higher risk. The purpose of this study is to quantify incidence, characterize the spectrum of knee injuries, and identify associated risk factors, while also integrating surgical data to describe patterns and management of anterior cruciate ligament (ACL) injuries in this population.

METHODS. In a prospective case-control study, 5614 injured Skiers and Snowboarders were recorded, at Parnassus ski resort, using a multivariate protocol, over 16 winter seasons (2007- 2025). Of those, 1657 (29.5%) sustained a knee injury with the majority occurring in skiers. General and sport-specific characteristics (e.g., age, sex, timing of injury, participation in lessons, equipment) were collected. At the same time, a control group of 846 uninjured athletes, randomly selected on the slopes, were also recorded on a similar protocol. Incidence was expressed as IPTSD (injuries per 1,000 skier-days) and MDBI (mean days between injuries), with skier-days estimated from total ticket sales. Risk factors were assessed using multivariable logistic regression with interaction testing, and injury types were analyzed with within-case multivariable models. In addition, data from 1,120 ACL reconstruction surgeries at our institution were reviewed to characterize ACL injury patterns and management in this population.

RESULTS. The overall rate of knee injury was 1.16 injuries per 1000 skier days (IPTSD) and remained broadly stable over time. The MDBI for a knee injury in skiers is 755 days and for snowboarders 1343 days. Selected key findings are summarized below. In the core multivariable model, females had higher odds of knee injury than males (OR 1.56, 95% CI 1.30–1.89; $p=0.000002$) while skiers had higher odds than snowboarders (OR 1.52, 95% CI 1.22–1.89; $p=0.000164$). Among adolescents aged 15–17y.o., snowboarders had substantially lower odds of knee injury than skiers in both sexes but especially in females (OR 0.31, 95% CI 0.13–0.70; $p=0.005$). Within skiers, male adolescents showed an age-related increase compared with ages 4–10y.o. (OR 1.95, 95% CI 1.00–3.81; $p=0.05$). Rental equipment was associated with increased odds of knee injury (OR 1.52, 95% CI 1.27–1.83; $p=0.000007$), with interaction analyses indicating a stronger rental-associated effect in skiers (OR 1.71, 95% CI 1.41–2.08; $p=6.6\times 10^{-7}$). A consistent interaction was observed in case–case analysis (LR $p=0.0107$), with ≥ 4 hours increasing the odds that an injury involved the knee among snowboarders (OR 1.59, 95% CI 1.12–2.24; $p=0.0086$). Injury patterns were dominated by knee strain (62.04%) while snowboarding was associated with lower odds of strain (OR 0.63, 95% CI 0.49–0.80; $p=0.000601$). Among skiing-related ACL reconstructions, 9.3% were classified as partial ACL injuries which almost always related to the posterolateral (PL) bundle.

DISCUSSION AND CONCLUSIONS. Knee injuries accounted for nearly one-third of recorded Snowsport injuries. Risk was higher in females and in skiers, and rental equipment was associated with increased odds—most notably among skiers. Exposure duration showed sport-specific effects, with prolonged activity (≥ 4 hours) increasing knee-injury odds among snowboarders but not among skiers. Surgical ACL cases provided additional, clinically relevant insights into injury patterns. Together, these findings support targeted prevention for high-risk subgroups, improved equipment practices, and risk-aware slope management.

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National Monitoring of Mountain Biking Injuries in Switzerland

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Keywords: mountain biking, injury prevention, accident data, monitoring

INTRODUCTION. Mountain biking has gained substantial popularity in Switzerland in recent years [1], accompanied by an expansion of mountain bike infrastructure in alpine regions. This development has been associated with a marked increase in injuries. Each year, more than 400 mountain bikers in Switzerland sustain severe injuries (defined as ≥ 3 months of work absence) [2], underlining the relevance of targeted injury prevention. Consequently, mountain biking has become an increasing priority of the BFU, Swiss Council for Accident Prevention. To enable evidence-informed prevention efforts, the BFU has implemented a nationwide injury surveillance system combining several complementary data sources. This contribution outlines the current injury profile of mountain biking in Switzerland and highlights key patterns of relevance for prevention.

METHODS. The injury monitoring currently comprises two data sources: (1) The BFU extrapolation model provides national estimates of the overall injury burden in Switzerland, based on a standardized population survey and accident records from mandatory accident insurers – the Federal Act on Accident Insurance (UVG) [2]. The UVG statistics is an extrapolation based on a 5% sample of all reported non-occupational accidents in Switzerland affecting persons aged approx. 16 to 65 years who are compulsorily insured under the UVG. (2) Fatal incidents have been systematically documented since 2000 within the BFU Statistics on Fatal Sports Accidents, a full survey drawing on multiple independent data sources and conducted in collaboration with external partners [3].

RESULTS. Each year, an estimated 16,340 Swiss residents are injured while mountain biking, over 400 of them severely, among mountain bikers of working age (approx. 16 to 65 years). Between 2015 and 2020, the annual number of mountain biking injuries has more than doubled from 8,990 to 18,920. The peak year for fatal incidents was 2020, with eight cases recorded. Since then, the number of fatal incidents has declined. Contusions are the most common injury, accounting for 46% of cases; another 17% involve distortion, sprain or strain, and 16% involve fractures. The most frequently affected body regions are the shoulder girdle and upper arm (19%), wrist, hand and fingers (14%), and the trunk (14%). Between 2015 and 2024, 32 fatal mountain biking incidents were recorded in Switzerland (28 men, 4 women), with a mean age of 54 ± 14 years. Two-thirds of fatal incidents resulted from falls from height, marking it as a key pattern for accident prevention efforts.

DISCUSSION. The observed burden of severe injuries and the predominance of falls from height among fatalities underline the importance of targeted prevention, particularly in settings with increased exposure to steep or elevated terrain. In response to these developments, the BFU has intensified its prevention efforts, including a nationwide trail rating system targeting falls from height as well as the promotion of a standardized accident reporting system for bike parks, which has been successfully used in snow sports for many years.

CONCLUSIONS. The mountain biking boom in Switzerland and the associated increase in severe injuries pose new challenges for accident prevention. A comprehensive monitoring system is essential to detect developments in accident occurrence and to enable targeted prevention in collaboration with all relevant stakeholders.

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Heart Rhythm monitoring with the wearable ECG during the endurance sports in athletes

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Keywords: Wearable, Electrocardiogram, Endurance sports

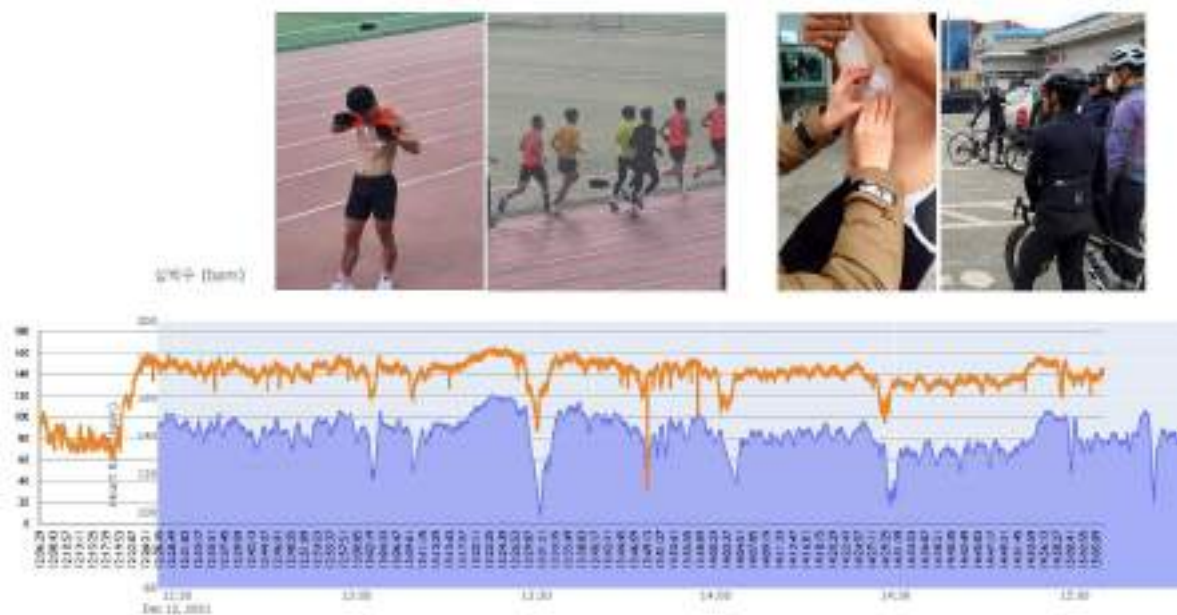
INTRODUCTION. Prescreening is crucial for athletes to reduce the risk of sudden cardiac death (SCD). However, 12-lead electrogram (ECG) alone is insufficient to predict SCD. This study aims to determine the feasibility of wearable ECG during endurance exercises. It intends to assess the effectiveness of wearable ECG in detecting cardiac arrhythmia that may arise during endurance sports.

METHODS. This prospective observational study focused on wearable ECGs for the athletes during endurance exercise. Before and after the exercise, all athletes underwent 12-lead ECG and routine laboratory test. Throughout a 3-hour endurance training course, participants were equipped with both wearable-ECG and heart rate trackers featuring photoplethysmography sensors (PPG-tracker).

RESULTS. The study included total sixteen endurance athletes, 6 cyclists, 10 runners and 6 triathletes, all of whom were Korean males, with an average age of 38 ± 11 years. Both the wearable-ECG and PPG-tracker effectively recorded heart rate trends during exercise for all participants (6 out of 6 cyclists, 8 out of 10 runners, and 6 of 6 triathletes; $r=0.978$). However, there were instances where two runners intermittently failed to record heart rate and ECG due to detachment issues with the wearable-ECG (2 out of 10 athletes). Notably, only the wearable-ECG could reliably identify significant arrhythmias during exercise. Wearable-ECG detected premature ventricular contractions in two athletes (one during rest and the other during exercise), whereas the PPG-tracker failed to identify these abnormalities.

Figure. Comparison of heart rate trends from PPG tracker and wearable ECGs ($p=0.978$)

Comparison of heart rate trend from Smartwatch(Garmin) vs. Wearable ECG (5-patch) ($p=0.978$)



CONCLUSIONS. The wearable-ECG monitoring during endurance exercises such as cycling and running is a highly feasible and superior method for early detection of cardiac arrhythmias in athletes. Such evaluations could potentially prevent unforeseen events, such as sudden cardiac death.

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SNOWSPORTS BENEFITS FOR ACTIVE HEALTHY AGING

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Keywords: skiing, proprioception, active aging, health benefits, compression wear

INTRODUCTION. Snowsports participation can support physical and psychosocial health outcomes for older participants (Burtscher et al., 2019). While people can participate in snowsports into older age (ASC, 2025), it is known that people typically experience age-related decline in proprioception (Yang et al., 2019). However, older ski instructors did not show the same age-related decline in proprioception (Dickson et al., 2022). Further, recent research has shown that compression socks may enhance proprioception (Marchant et al., 2023). This research explores i) if older recreational snow ski participants experience similar proprioception benefits, and ii) whether lower limb compression garments enhance proprioception. The garment choice reflects real world snowsport conditions.

METHODS. 34 active recreational snow ski participants (age-range 60–81 yrs, \bar{x} =68.7 yrs), were recruited over 2024–25. Lower limb proprioception was measured via the Active Movement Extent Discrimination Assessment (AMEDA) device in two conditions: loose shorts and wearing sport-relevant compression gear (Bracelayer KS1 Vent 7/8 Knee Support) (Figure). SPSS was used for between group comparisons via independent and paired samples t-tests. UC human ethics approval granted for this project #12095.



Figure 1: AMEDA use. Wearing Bracelayer KS1 Vent, 7/8 Knee Support

RESULTS. The AMEDA scores when not wearing compression garments for all participants ($n=34$) ranged from .54-.73 (\bar{x} =.633) (higher is better). An independent sample t-test did not show a significant difference between these AMEDA scores for the 24 females (\bar{x} =.624, SD =.05) and 10 males (\bar{x} =.654, SD =.05 $t(32) = -1.66, p = .107$).

To compare AMEDA scores with and without compression garments, paired sample t-tests were conducted. For the whole group, there was a significant increase in AMEDA scores from *no compression* (\bar{x} =.633, SD =.049) to *compression* (\bar{x} =.656, SD =.044, $t(33) = -3.31, p = .001$ (two-tailed)). Data for AMEDA scores without compression were recoded into two groups by the mean AMEDA score from prior research (<.67 and .67+). For group 1, a paired samples t-test revealed a significant increase in AMEDA scores from *no compression* (\bar{x} =.608, SD =.033) to *compression* (\bar{x} =.640, SD =.042, $t(23) = -3.663, p = .001$ (2-tailed)). For group 2 (.67+), there was no significant increase from *no compression* (\bar{x} =.692, SD =.187) to *compression* (\bar{x} =.693, SD =.023, $t(9) = -.189, p = .84$ (2-tailed)).

DISCUSSION and CONCLUSIONS. While AMEDA scores for older recreational ski participants were slightly lower than for older ski instructors (females .62 *c.f.* .65; males .65 *c.f.* .68) (Dickson et al., 2022), there was not the same decline in proprioception observed in healthy older participants (Yang et al., 2019). For those with baseline (*no compression*) scores lower than .67, their AMEDA scores when wearing ski-relevant compression garments improved, this is consistent with research using compression socks (Marchant et al., 2023).

This exploratory research of older recreational snow ski participants suggests that snowsports may protect against age-related proprioception decline. Further, using sport-relevant lower limb compression garments may improve proprioception scores that may be beneficial for performance, fatigue reduction, and ultimately injury reduction.

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The Overlooked Side of Snowsports: How malnutrition affects young skiers and snowboarders

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Keywords: snowsports, dizziness, hydration, nutrition, pediatric

INTRODUCTION. Pathological presentations in a medical facility of a ski resort are often overlooked. Yet they may affect athletes' performance and, in some cases, lead to acute symptoms requiring medical attention. One common—but under-recognized—pattern is inadequate nutrition and hydration before or during skiing, which is particularly relevant for children, who may have limited energy reserves and may not recognize early warning signs. The purpose of this study is to determine the effects of malnutrition in Snowsport athletes, summarize the available evidence from the literature, and complement it with our clinical observations. Finally, we present a brief descriptive statistical analysis of the recorded cases within these categories.

METHODS. In a retrospective descriptive analysis, 1156 non-traumatic medical incidents were recorded, at Parnassus ski resort, using a multivariable protocol, over 16 winter seasons (2007- 2025). Of those, 668 (57.8%) were athletes: 524 skiers (78.4%) and 144 snowboarders (21.6%). A control group of 846 uninjured athletes was randomly sampled on the slopes using the same protocol. Pediatric status was defined as age <18 years old. A targeted narrative synthesis incorporated key sources on youth winter-sport nutrition while risk factors were examined with a univariate case control analysis.

RESULTS. Paediatric participants were more frequent among athlete pathological presentations than among controls (42.9% vs 27.2%), corresponding to a crude odds ratio (OR) of 2.01 (95% CI 1.54–2.62; $p < 0.001$). Within the paediatric subgroup, the distributions of age, sex, and sport (skiing vs snowboarding) were comparable between cases and controls. Some of the most frequent non-injury presentation categories were dizziness (20.4%), syncope/presyncope (7.9%), and weakness/fatigue (7.9%). In these categories, clinical notes frequently included reports—present in more than 60% of cases—consistent with inadequate pre-exercise intake (e.g., “didn’t eat,” “fasting,” “only coffee,” “ate very little,” “hadn’t eaten since yesterday”), and occasionally insufficient fluid intake. These observations align with winter-sport literature showing that maintaining adequate energy intake and hydration is difficult in cold, dry alpine settings—especially in youth—due to reduced thirst perception and cold-related fluid losses. General guidance for young athletes emphasizes planned meal timing, portable refueling, and scheduled drinking, and breakfast appears particularly beneficial before prolonged morning sessions (>60 min), which mirrors typical ski-day demands. Based on our clinical experience, the alpine environment and on-slope logistics can mask dehydration and delay refueling, underscoring the need for proactive nutrition and hydration screening during triage.

DISCUSSION AND CONCLUSIONS. Pathological presentations among Snowsports athletes were dominated by dizziness and weakness complaints, with children over-represented. Recurrent “missed meal” reports are clinically plausible within the winter-sport nutrition/hydration evidence base and support simple prevention messaging—planned breakfast, portable carbohydrate-rich snacks during prolonged slope exposure, and scheduled fluid intake—especially for pediatric participants. Our findings can further educate children and adolescents, parents and ski schools’ instructors to reduce symptom burden, improve the on-slope experience, and support safer participation in winter sports.

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Cardiopulmonary Exercise Responses to Uphill Treadmill Testing in Elite Iranian Sky Running and Ski Athletes

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Background: Cardiopulmonary exercise testing (CPET) provides comprehensive insight into aerobic capacity, ventilatory thresholds, and exercise tolerance in elite athletes. While CPET is widely used in endurance sports, comparative physiological data across mountain and winter sports, particularly between endurance- and skill-oriented athletes, remain limited.

Objective: This study aimed to characterize cardiopulmonary exercise responses in elite Iranian mountain and skiing athletes and to compare physiological profiles across endurance-based (sky running, cross-country skiing) and non-endurance (alpine skiing/snowboarding) disciplines using a standardized uphill running protocol.

Methods: This cross-sectional study employed maximal treadmill-based CPET with breath-by-breath gas analysis. Participants included 25 sky runners, 14 cross-country skiers, and 10 alpine skiers/snowboarders. Peak oxygen uptake (VO_{2peak}), anaerobic threshold (AT), respiratory compensation point (RCP), oxygen pulse, heart rate responses, pulmonary function, and exercise duration were assessed. Multivariable linear regression models evaluated associations with sport discipline, sex, age, and body size.

Results: Forty-nine elite athletes completed CPET (34 males, 15 females; mean age 29.3 ± 8.3 years). Mean VO_{2peak} was 48.3 ± 7.4 mL·kg⁻¹·min⁻¹. Sport discipline, sex, and BMI were independently associated with VO_{2peak} and VO_{2RCP} . Cross-country skiers demonstrated the highest aerobic capacity and ventilatory thresholds, followed by sky runners, while alpine skiers/snowboarders exhibited significantly lower values. Discipline-related differences were suggestive of greater differentiation among female athletes; however, interpretation is limited by small subgroup sample sizes. Oxygen pulse was primarily influenced by sex, whereas peak heart rate was driven by age alone. Exercise duration showed the strongest differentiation between endurance- and non-endurance-oriented disciplines.

Conclusions: Elite mountain athletes display distinct cardiopulmonary phenotypes shaped by sport specialization, with expected modulation by biological sex. Endurance disciplines confer superior aerobic capacity and exercise tolerance. These findings highlight the importance of discipline-specific interpretation of CPET and support individualized training strategies in mountain and winter sports.

Keywords: CPET, peak VO_2 , aerobic capacity, skiing, mountaineering, endurance training

Performance of Children's Alpine Ski 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]. To preserve the engineering success of alpine SBB systems with new types of SBB systems (touring, walking, multi-norm, etc.), a study was conducted previously to determine the release torque range of adult alpine bindings (Type A) with alpine boots (ISO 5355) according to the standard ASTM F504; for that study, Tests 1.6 and 1.10 were used to model forward and backward twisting falls [2]. That study suggested that *all types* of SBB systems be evaluated with ASTM F504 and that the release torques for F504 Tests 1.6 and 1.10 be within 35% and 45% of the pure twisting release value [2]. Children's alpine (Type C) SBB systems are designed for lower release levels and smaller boot sole lengths. Due to these variables, it is possible that the performance of Type C SBB systems would not be the same as Type A systems. To this end, we tested Type C SBB systems (classic children's alpine bindings) to determine their response in simulated forward and backward twisting falls using the standard test methods in ASTM 504.

METHODS. 8 Type C children's alpine ski bindings (no GripWalk systems) were tested using ASTM F504 and an ISO 9838 Type C test sole. The Type C SBB system was set to a release value according to skier codes C, E, or G from ISO 11088 Table B.1 (chosen in a random order). The SBB system was then checked using pure twisting release (Test 1.1) and indicator values on the bindings were adjusted until the inspection parameters were met. After passing inspection, the SBB system was misted with water according to F504, and Test 1.1 was performed again. In a random order, simulated forward and backward twisting falls (Tests 1.6 and 1.10) were completed, with 3 trials in each condition.

RESULTS. 288 tests were conducted. For all forward twisting falls (Tests 1.6), only one single trial exceeded the suggested allowable range of 135% of the Test 1.1 release value; this was 137% of Test 1.1. 15% of backward twisting falls (Tests 1.10) tested above 45% of the Test 1.1 release value. Of this 15%, when the 3 trials were averaged, only 8% of the backward twisting falls failed to meet this performance standard.

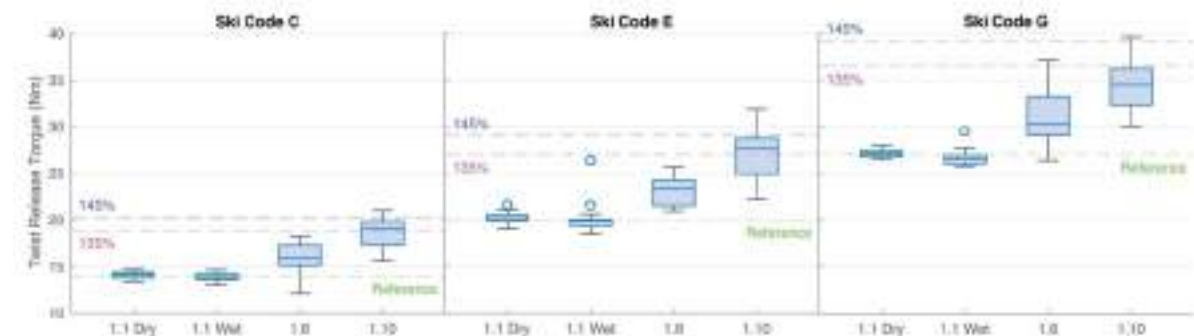


Figure 1. Box plots of twisting release torques for 3 indicator settings (related to skier codes C, E, and G) for ASTM F504 Tests 1.1, 1.6, and 1.10.

CONCLUSIONS. Based on the response of children's alpine SBB systems, we suggest that children's SBB systems should have a slightly greater tolerance range than adult systems for simulated forward and backward twisting releases (Tests 1.6 and 1.10). For Tests 1.6 and 1.10, we suggest that a range of 140% and 150% of the Test 1.1 tests for children's SBB systems, as this would match the release and retention envelopes of the alpine systems that have successfully reduced lower leg injuries. This range would also apply to new walking (GripWalk) SBB systems.

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The effect of carbon shin pads on ski boot stiffness

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Keywords: Ski boot, stiffness, shin pads

INTRODUCTION. Despite several efforts over the past decade to enhance alpine skier safety, injury rates have not significantly declined (Barth et al. 2021; Haaland et al. 2016). The causes of injuries are complex and multifactorial (Bere et al. 2014). According to expert ratings, i.a. the system ski, binding, plate, and boot transmits forces too directly (Spörri et al. 2012).

Shin pads are frequently employed in skiing to address medical issues such as shin splints. Their impact on ski boot mechanics, especially stiffness, and overall skiing performance is not well understood. This study therefore sought to quantify any stiffness-enhancing effect of shin pads via force plate measurements with athletes and laboratory-based boot flexion testing.

METHODS. For the individual measurements with athletes, the ski boot was rigidly fixed on a force plate. The athlete performed two controlled movements: (1) antero-posterior flexion/extension and (2) medio-lateral bending. A camera recorded the antero-posterior and medio-lateral angles of the lower leg. Subsequently, the forward and lateral torque about the ski boot's pivot axis was calculated.

Separately, a prosthetic flex measurement test rig was employed to measure the bending stiffness of the ski boots during simulated flexion and the imitation of an edging movement.

The athletes used their custom-fitted shin pads. For the test rig evaluations, a separate set of shin pads was fabricated to precisely match the dimensions of the prosthesis used in the rig.

RESULTS. Both test methods showed an increase in ski boot stiffness when using shin pads:

In the individual flex measurement, the forward boot flex increased by 24.8 % in average, and lateral boot flex increased by 24.3 % in average. In the prosthetic flex measurement, the average stiffness increased by 14.9 % in forward boot flex and by 9.8 % in lateral boot flex.

DISCUSSION. Shin pads led to an increase in ski boot stiffness. While the force plate setup introduced some variability due to human motion, the prosthetic setup offered high reproducibility. The extent of stiffening varied depending on pad geometry and thickness, boot type and size, and buckle tension.

CONCLUSIONS. Beyond mitigating the consequences of injuries, the examined carbon shin pads also contribute to stiffening the ski boot. This might make force transfer in skiing more direct and might, in some situations, increase the likelihood of injury.

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Numerical Evaluation of a Back Protector in Critical Skiing and Mountain Biking Falls

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Keywords: spinal injury, back protector, skiing, mountain biking, crash scenario, human finite element model

INTRODUCTION. Spinal injuries represent 30 to 45 % of severe injuries (Injury Severity Score > 15) in skiing and mountain biking (MTB) [1]. Back protector (BP) devices are widely worn as a protection against these injuries, however their effectiveness on realistic sports accidents has not been evaluated yet. Recent accident reconstruction studies identified forward falls with back impact and rolling motion, spinal hyperflexion, and compression fractures (Magerl type A) as the primary vertebral fracture mechanisms in MTB crashes [2,3]. Similar crash configuration [4], impact speed [5], and vertebral fracture typologies [6] suggest comparable injury mechanisms in skiing. This study aims to promote a combined experimental - numerical methodology to evaluate foam energy dissipation capabilities in a commercial BP under representative skiing and MTB accident scenarios.

METHODS. The polyurethane BP was experimentally characterized using uniaxial compression and drop tower tests, which were numerically reproduced using finite element models with a rate-sensitive Fu–Chang material calibrated to experimental force–time responses. The full BP model was then validated through drop tests from 0.6 m and 1.5 m on three impact zones (Fig. a).

To reproduce the typical injury mechanisms identified — forward falls with back impact and rolling motion, spinal hyperflexion, and compression fractures [2,3] — three representative crash configurations were defined using the finite element human body model THUMS v4.1. These simulations involved rigid-surface impacts to the mid-lower back ($\theta = 0^\circ$), lower back ($\theta = 45^\circ$), and upper back ($\theta = -30^\circ$) and subjected the body to combined normal (9.0, 9.0, 8.0 $\text{m}\cdot\text{s}^{-1}$), tangential (6.0, 6.0, 7.5 $\text{m}\cdot\text{s}^{-1}$), and rotational velocities (5.5, 5.5, 7.5 $\text{rad}\cdot\text{s}^{-1}$), respectively (Fig. b). The BP was fitted to the model’s back geometry and tied to the skin. Impact forces and vertebral fracture risk were assessed using trabecular von Mises strain (7.5% threshold [7]) in simulations with and without the BP.

RESULTS. The BP model’s mechanical response satisfactorily matched the impact force time-histories observed in the experimental drop tests, with Correlation Analysis (CORA) scores ranging between 0.61 and 0.69 (Fig. a). During the crash, the BP effectively reduced the impact force transmitted to the athlete’s back, with reduction of 41% in the mid-lower back, 32% in the lower back, and 41% in the upper back. However, the maximum vertebral strains were not significantly reduced by BP use and remained above the fracture threshold (Fig. c, d).

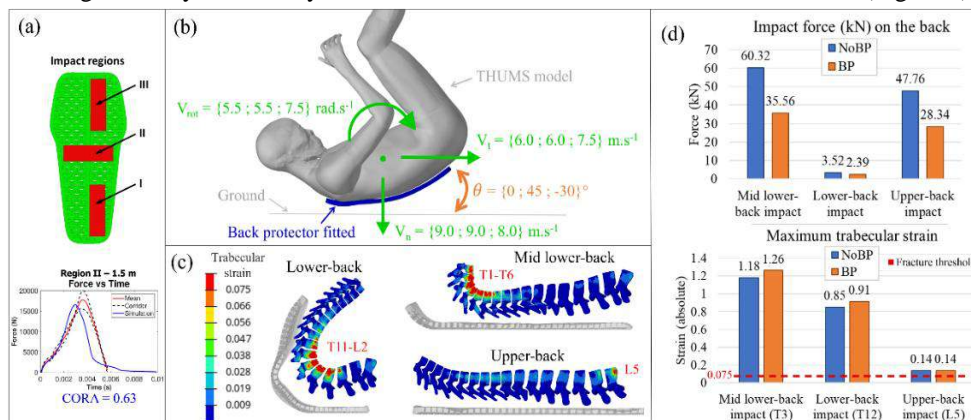


Figure (a) FE model of the BP validated for drop tests. **(b)** Simulation parameters. **(c)** Compression mechanisms their associated fracture prediction. **(d)** Impact force on the back (top) and max trabecular VM strain (bottom).

DISCUSSION AND CONCLUSIONS. Across the three realistic injurious crashes studied, the BP significantly reduced the impact force on the back but did not reduce the risk of vertebral fracture, as assessed by vertebral strain levels. It suggests that energy dissipation alone does not fully account for vertebral fracture risk mitigation, and that control of spinal hyperflexion mechanisms during these accidents also represents a major safety issue.

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From Video to Joint Kinematics: A Markerless Workflow for Skiing Injury Analysis

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Keywords: Markerless motion capture, Alpine skiing, Skiing injury, Inverse kinematics, Snow sports safety

INTRODUCTION. Understanding the mechanisms of skiing injuries is essential for improving prevention strategies and return-to-sport decision-making (1). However, most biomechanical analyses rely on laboratory-based motion capture systems, which are not applicable to real-world injury situations. Markerless, video-based approaches offer the potential to extract kinematic information from both controlled experiments and real injury videos, but their accuracy and limitations require careful evaluation. The purpose of this study was to present and validate a markerless kinematic workflow and to demonstrate its application to a real-world skiing injury case.

METHODS. Jump-landing tasks were recorded in a laboratory setting using a marker-based motion capture system (Vicon) as reference. The same trials were reconstructed using a markerless pipeline based on 4D Humans, generating three-dimensional human meshes. Selected mesh landmarks were used to drive inverse kinematics in OpenSim to estimate lower-limb joint angles. Knee joint kinematics obtained from the markerless workflow were compared to the reference system using mean absolute errors (MEA). The validated workflow was additionally applied to a real-world skiing injury video to extract knee joint kinematics (Fig.).

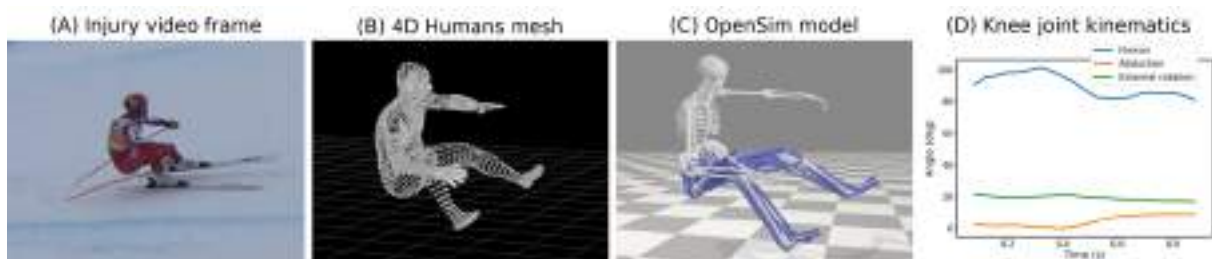


Figure: From injury video (A) to 3D reconstruction (B), inverse kinematics (C), and joint kinematics (D).

RESULTS. For the jump-landing trials, mean absolute errors for the knee joint were $2.7 \pm 4.8^\circ$ for flexion/extension, $1.1 \pm 2.9^\circ$ for adduction/abduction, and $7.6 \pm 6.7^\circ$ for internal/external rotation. In the skiing injury case study, the workflow produced continuous knee joint kinematics, with flexion angles ranging from 81° to 101° , abduction from 0° to 9° , and external rotation from 17° to 21° during the analysed sequence.

DISCUSSION The results indicate that markerless reconstruction combined with inverse kinematics can provide meaningful lower-limb kinematics in real-world skiing injury scenarios. In the laboratory setting sagittal- and frontal-plane knee kinematics showed high agreement with the reference system, while in transverse-plane motions increased deviations were observed. In the skiing injury case study, the extracted knee joint kinematics showed continuous and biomechanically plausible trajectories for flexion, abduction, and external rotation. A key limitation is the simplified modeling of the foot segment in the markerless reconstruction, which may affect tibial orientation and could subsequently explain the deviations in transverse-plane knee kinematics.

CONCLUSIONS. The proposed markerless workflow enables extraction of joint kinematics from skiing injury videos that are otherwise inaccessible to traditional motion capture systems. Improving foot and ankle modeling represents an important area for future development.

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An IMU Motion Capture System for Snowboarding Based on Biomechanical Constraint Optimization

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Keywords: Keywords: Snowboarding; IMU Motion Capture; Biomechanical Constraints; Pose Optimization;

INTRODUCTION. Motion capture is critical for snowboarding technique analysis, training optimization, and injury prevention. IMU-based systems, featuring portability and real-time performance, are widely studied for sports motion analysis. However, IMU data suffers from cumulative drift and pose distortion during prolonged operation, compromising motion reconstruction accuracy[1]. This study developed a snowboarding-specific IMU motion capture system, integrates human biomechanical constraints for pose optimization, and validates its accuracy against a high-precision optical system, aiming to provide a reliable tool for snowboarding motion analysis.

METHODS. 10 IMU sensors were mounted on upper arms, forearms, thighs, calves, back, and pelvis to collect motion data for 3D human pose reconstruction. Biomechanical constraints were integrated for pose optimization, including physiological joint motion ranges and a critical constraint of fixed inter-foot distance during snowboarding. The IMU system and an optical motion capture system collected data synchronously, with knee and hip joint angles extracted as key motion parameters.

RESULTS. As shown in Table 1, the optimized IMU system improved pose reconstruction accuracy, with reduced mean absolute error (MAE) and root mean square error (RMSE) for key joint angles compared to unoptimized data. As shown in Figure 1(b) Joint angle curves exhibited strong consistency with the optical reference system.

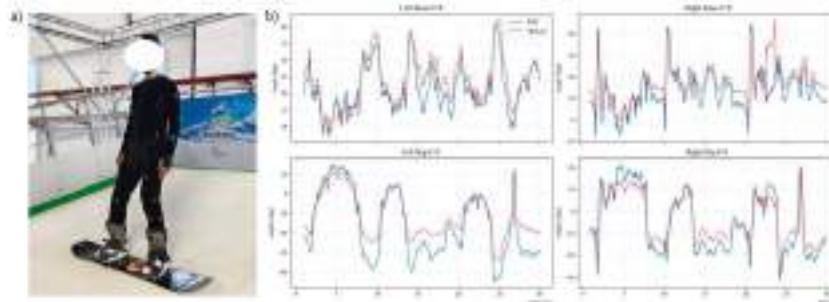


Figure 1. a) Snowboarder equipped with IMU sensors and optical motion capture markers during testing. b) Comparison of joint angles acquired by IMU and optical motion capture systems.

Table 1. joint angle error comparison between original and optimized IMU systems

Joint Angle	Original MAE(°)	Original RMSE(°)	Ours MAE(°)	Ours RMSE (°)
Left Knee F/E	6.06	6.46	2.39	3.04
Right Knee F/E	4.13	5.97	4.79	6.98
Left Hip F/E	14.62	15.63	5.34	6.80
Right Hip F/E	12.34	13.11	3.80	4.50

DISCUSSION. Integration of biomechanical constraints—especially the snowboarding-specific fixed inter-foot distance—effectively mitigates IMU drift and distortion. This motion capture system provides potential extensions to snowboarding games and esports.

CONCLUSIONS. This portable IMU system achieves high-precision joint angle estimation via biomechanical constraint optimization, offering a reliable alternative to optical systems for field-based snowboarding analysis. It delivers more accurate motion data to support snowboarding-related research and injury preventions

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Investigating dry ski–snow friction

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Keywords: ski–snow friction, friction mechanisms, dry friction, quasi-liquid layer

INTRODUCTION. The low resistance encountered by skis on snow has long been attributed to a combination of co-existing mechanisms, including dry friction, lubrication by frictional meltwater, and capillary suction (Colbeck, 1988), making the assessment of individual contributions challenging. Experimental studies that systematically characterise ski–snow friction mechanisms remain scarce. The objective of the present work was to investigate dry ski–snow friction.

METHODS. Experiments were performed in the snow laboratory of the Research Center Snow, Ski and Alpine Sports at the University of Innsbruck (Austria), using a linear tribometer. The test specimen was a flat slider (100 × 5 cm) made of medium-density fibreboard (MDF) with an ultra-high molecular weight polyethylene (UHMWPE) base, to which a liquid wax (Hydro warm, HWK-Kronbichler GmbH, Ebbs, Austria) was applied. The tests were conducted at a snow temperature of –8 °C under conditions known to preclude the formation of frictional meltwater (Lever et al., 2018). The temperature was further lowered below –30 °C using dry ice to eliminate any potential contribution from a quasi-liquid layer, thereby ensuring that dry friction was the sole present mechanism. In addition, conditions representative of cross-country skiing were also investigated.

RESULTS. The friction coefficient was found to be significantly higher at a snow temperature below –30 °C than at –8 °C. At both snow temperatures, an increase in the normal pressure resulted in a decrease in the friction coefficient. At a snow temperature below –30 °C, the friction coefficient decreased with increasing sliding speed, whereas at –8 °C it increased.

DISCUSSION. A comparison of the measured friction coefficients with theoretical considerations indicated that the friction mechanisms change with temperature. At a snow temperature below –30 °C, tearing out of grains appeared to be the primary contribution to friction, whereas at –8 °C friction was more likely governed by the shearing of asperity tips (abrasion). The findings suggest that, across all examined conditions, friction can be explained by the identified mechanisms, together with thermal effects and granular lubrication. While the quasi-liquid layer (QLL) is essential to explain friction on ice, its role in ski–snow friction appears to be considerably less significant.

CONCLUSIONS. We investigated ski–snow friction at comparatively low temperatures. Dry friction resulted to be not a single, well-defined snow–friction mechanism. Instead, its nature varies with temperature, leading to fundamentally different frictional behaviours. Using further thermal and mechanical effects, we were able to completely interpret the measurement results.

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COMPENSATORY MOTOR STRATEGIES AND CHANGES IN MUSCLE ACTIVITY DURING PROLONGED ALPINE SKIING: A FIELD-BASED SINGLE SUBJECT CASE STUDY

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Keywords: Alpine skiing, EMG, compensatory motor strategies

INTRODUCTION. Alpine skiing imposes substantial neuromuscular and physiological demands due to repeated eccentric and concentric muscle contractions under high mechanical loads. Previous research has examined fatigue-related changes in muscle activity during skiing, yet most studies have relied on short sampling durations, often analyzing only a few turns or a single run. As a result, little is known about changes in neuromuscular responses under cumulative physical load over multiple consecutive days. Therefore, the purpose of this study was to examine changes in muscle activation, compensatory neuromuscular strategies, and performance changes over three consecutive days of alpine skiing in an elite skier.

METHODS. A 27-year-old elite female skier completed a field-based protocol over three days, which consisted of two measurement runs and six free runs each day. Surface electromyography (sEMG) was recorded unilaterally from seven muscles. Heart rate (HR) and ratings of perceived exertion (RPE, Borg 6-20) were measured post-run. EMG root mean square (RMS) amplitudes were analyzed using repeated-measures ANOVA.

RESULTS. HR and RPE increased within each day, with an elevated baseline RPE on Day 3. Maximal HR during the final measurement run across the three days averaged 178 bpm (92% HR_{max}), and ending RPE's were 17, 17, and 18 on Days 1, 2, and 3, respectively. EMG activity of most of the muscles of the outside leg decreased by in average of 16% (e.g., erector spinae: -13%, gluteus medius: -22%, rectus femoris: -19%, biceps femoris: -16%, vastus lateralis: -8%, peroneus longus: -21%), while inside-leg muscles increased by in average of 27% (e.g., erector spinae: +10%, gluteus medius: +57%, rectus femoris: +18%, biceps femoris: +28%, peroneus longus: +19%). However, the performance marker (time per turn) did not change significantly between measurement runs 1 and 2 for all three days.

DISCUSSION AND CONCLUSIONS. These findings suggest that an elite skier adopted compensatory motor strategies to maintain performance by redistributing muscular effort to the inside leg under increasing internal load. As skiing progressed, perceived exertion was rated as very hard (RPE = 17 and 18). While effective short term, these adaptations may increase mechanical stress on specific joints and elevate injury risk, such as overuse injuries or joint instability. Identifying such compensatory patterns may help guide injury prevention strategies during high level skiing or training. These findings support the concept of flexible motor control in elite athletes and underscore the importance of understanding compensatory strategies. Awareness of athletes' perceptions of effort may also be important in minimizing injury risks. Early identification of these patterns may help not only in optimizing performance but also in developing targeted training programs to minimize injury risk.

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Functional Adaptation of Knee Extensors to Chronic Eccentric Loading: A Key Protective Mechanism Against High-Force Injury in Alpine Skiing

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Keywords: Alpine Skiing, Eccentric Contraction, Knee Extensor, Muscle Architecture, Optimum Angle

INTRODUCTION. Alpine skiing is characterized by a unique loading environment involving slow and forceful eccentric muscle actions during turns. While skeletal muscles are known to adapt both structurally and functionally to repeated loads, the specific adaptations resulting from the predominant eccentric loading in skiing remain under-explored. This study aimed to investigate the force production capacity and muscle architecture of the knee extensors in skilled alpine skiers, comparing them with road cyclists who experience similar joint kinematics but opposite (concentric-dominant) loading patterns.

METHODS. Approved by Yonsei University IRB (No. 7001988-202010-HR-1007-02). Eighteen male participants (9 alpine skiers, 9 road cyclists) were recruited. Isometric knee extension torque was measured at four angles (40°, 60°, 80°, 100°), and isokinetic torque (concentric and eccentric) was assessed at angular velocities of 30°/s and 150°/s using a multi-joint dynamometer. The torque-angle and torque-velocity relationships were analyzed to determine the peak torque and the optimum angle of peak torque. Additionally, muscle thickness, fascicle length, and pennation angle of the vastus lateralis (VL) were measured using B-mode ultrasonography.

RESULTS. Skilled skiers demonstrated significantly higher normalized isometric torque at 100° of knee flexion compared to cyclists ($77.97 \pm 8.21\%$ vs $65.54 \pm 4.60\%$; $p=.002$). In isokinetic tests, skiers exhibited significantly greater normalized eccentric torque at slow velocity (ECC 30: $104.68 \pm 5.21\%$ vs $90.41 \pm 6.98\%$; $p=.0001$). The optimum angle for peak torque was significantly larger (indicating more flexed positions) in skiers than in cyclists across isometric ($80.47 \pm 1.73^\circ$ vs $75.03 \pm 4.57^\circ$; $p=.030$) and slow isokinetic conditions. No significant differences were observed between groups in VL fascicle length ($p=.922$) or pennation angle ($p=.930$).

DISCUSSION. The results demonstrate that the knee extensors of alpine skiers have undergone specific functional adaptations to their high-load eccentric environment. The significant shift in the optimum angle toward greater knee flexion—observed in isometric ($80.47 \pm 1.73^\circ$, $p=.030$) and slow isokinetic conditions (ECC 30: $80.15 \pm 4.60^\circ$, $p=.028$; CON 30: $79.63 \pm 5.04^\circ$, $p=.002$)—provides clear mechanical evidence of increased series compliance at longer muscle lengths. This adaptation allows for stable force production during deep flexion phases of a turn, effectively protecting the joint under extreme mechanical stress.

Crucially, these functional gains, particularly the superior normalized eccentric torque at slow velocity (ECC 30: $104.68 \pm 5.21\%$ vs. $90.41 \pm 6.98\%$, $p=.0001$), were achieved without significant alterations in gross muscle architecture. Since no significant differences were found in fascicle length ($p=.922$) or pennation angle ($p=.930$), the enhanced force capacity cannot be attributed to morphological changes such as muscle hypertrophy.

CONCLUSIONS. The unique loading environment of alpine skiing induces task-specific functional adaptations in the knee extensors, characterized by shifted optimum angles and enhanced eccentric force capacity. These adaptations are essential for maintaining joint integrity and preventing injuries during high-force turn mechanics. However, the lack of structural differences between groups indicates that such functional readiness is not automatically guaranteed by standard strength gains.

Conventional training programs, which typically emphasize concentric actions or mid-range joint angles, appear insufficient to elicit the specific neuromechanical responses required for skiing. Therefore, there is a clear need to move beyond traditional methods and develop specialized training protocols. Evidence-based programs focusing on high-load eccentric actions at deep flexion angles must be prioritized to effectively prepare the musculoskeletal system for the specific demands of alpine skiing and to minimize the risk of injury.

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Association Between Tibial Torsion, ACL Injury, and Functional Biomechanics in Elite Alpine Skiers

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Keywords: alpine skiing; anterior cruciate ligament (ACL); tibial torsion; kinematics; motion analysis

INTRODUCTION: Tibial torsion is an important anatomical factor influencing lower-extremity biomechanics, yet its interaction with ACL injury history in elite alpine skiers remains unclear.

METHODS: Twenty elite alpine skiers participated in this study (ACL-reconstructed: n = 7; non-injured: n = 13). Static tibial torsion was assessed using the Transmalleolar Axis and Thigh–Foot Angle measurements. Dynamic lower extremity kinematics were analyzed during Squat, Single-Leg Squat, and Lunge tasks using a markerless motion capture system. A two-way ANOVA was conducted to examine the main and interaction effects.

RESULTS. Rotational deformity was identified in 70% of participants. A significant interaction effect between ACL-reconstructed skiers with tibial torsion demonstrated a distinct stiffness strategy, characterized by reduced knee valgus and hip rotation with compensatory ankle dorsiflexion. ACL-reconstructed skiers with normal tibial alignment exhibited an “Instability Strategy”

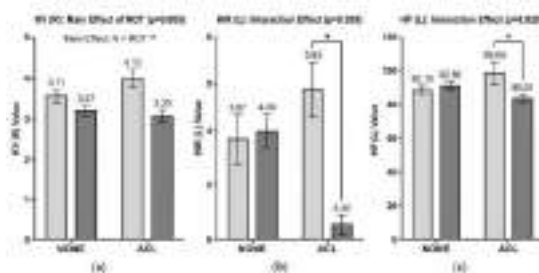


Figure 1. Significant main and interaction effects of tibial rotation and ACL status on lower-extremity kinematics. Light grey bars indicate normal alignment and dark grey bars indicate rotational deformity. Values are mean ± standard error. *p < 0.05, **p < 0.01.

DISCUSSION. Elite alpine skiers adopt distinct compensatory movement strategies following ACL reconstruction depending on underlying tibial alignment. Excessive ankle compensation may mask frontal-plane control in skiers with tibial torsion, whereas skiers with normal alignment may continue to exhibit neuromuscular instability.

CONCLUSIONS. Rehabilitation and injury prevention programs for elite alpine skiers should be individualized based on anatomical screening. Skiers with tibial torsion may benefit from mobility decoupling strategies, while those with normal alignment require targeted interventions to enhance dynamic stability and symmetry

Ethics Statement: Institutional Review Board (IRB) of CHA University, Pocheon-si, Korea (IRB No. 1044308-202509-HR-289-02).

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Rethinking Helmet Design in Snowsports: The Role of Fit, Compliance, and Human Factors in Reducing Head Injury Risk Under the Virginia Tech Snow Sports STAR Protocol

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Keywords: Safety, design, concussion, helmet

INTRODUCTION

Head injuries in alpine skiing and snowboarding include concussion, skull fracture, and traumatic brain injury. Although helmet adoption has increased, laboratory performance varies substantially across commercially available designs. The Virginia Tech Snow Sports STAR protocol evaluates helmet performance by estimating concussion risk based on measured peak linear acceleration and rotational velocity across standardized impact configurations. This study evaluates a segmented, non-rigid helmet frame architecture using the Virginia Tech STAR methodology and considers human factors such as fit stability and user adoption.

METHODS

Helmet performance was evaluated using the Virginia Tech Snow Sports STAR protocol. Testing consists of 12 drop-tower impacts representing three locations (front, side, rear) and two anvil angles (high and low), with velocities derived from real-world snow sport head impacts. For each impact, peak linear acceleration and rotational velocity were measured. Concussion risk was calculated using the STAR methodology, in which each impact's estimated concussion probability is weighted and summed to produce an overall STAR score. Lower STAR scores indicate lower modeled concussion incidence under defined laboratory conditions.

FIS 2013-certified and slalom racing helmets were excluded from comparison due to differing certification criteria, design intent and adoption. The comparison group therefore reflects helmets intended for general recreational snow sport use. Qualitative observations regarding helmet fit stability, displacement during falls, and user acceptance were collected to inform contextual interpretation.

RESULTS

The evaluated segmented non-rigid helmet achieved a STAR score of 0.42. Among non-FIS 2013 slalom helmets currently listed in the Virginia Tech Snow Sports database, the next lowest published STAR score was 0.48. Across the full dataset, published STAR scores ranged from 0.42 to 3.10, indicating substantial variation in modeled concussion incidence under standardized impact conditions.

The proportional difference between 0.42 and 0.48 corresponds to an approximate 12.5% lower modeled concussion incidence relative to the next lowest non-FIS 2013 slalom helmet under the STAR weighting model. Qualitative observations indicated improved perceived fit conformity, reduced helmet displacement during falls, and positive user acceptance compared with conventional rigid-shell designs.

DISCUSSION

The segmented architecture incorporates interconnected structural elements that permit distributed compliance during impact, allowing controlled deformation prior to peak liner compression. Because STAR integrates both linear and rotational components into a weighted concussion risk estimate, lower overall scores reflect reduced modeled concussion probability under standardized laboratory conditions.

The observed range of STAR scores highlights the influence of structural design differences on laboratory-modeled concussion risk. In addition to mechanical performance, helmet stability, conformity to the head, and user acceptance may influence real-world protective effectiveness. User feedback indicates a growing adoption rate, and well as validation of the segmented shell's ability to conform to the user to present superior comfort to traditional helmet shells.

CONCLUSIONS

Under the Virginia Tech Snow Sports STAR protocol, the evaluated segmented non-rigid helmet architecture demonstrated the lowest published STAR score among non-FIS 2013 slalom helmets currently listed in the database. Structural segmentation and distributed compliance may represent an alternative design strategy for reducing modeled concussion risk in recreational snow sport helmets, alongside improvement in user factors, such as wearability, comfort, fit and style. The non-rigid helmet presents an opportunity to advance concussion reduction, alongside user satisfaction on the mountain.

Disclosure: The author is the founder of Anti Ordinary Pty Ltd, manufacturer of the helmet evaluated.

Head Accelerations during Falls in Snowboard Halfpipe – A Case Study in Comparison to a Comprehensive Reference Dataset

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Keywords: Halfpipe, biomechanics, aerials, falls, brain injury

INTRODUCTION. Snowboard freestyle has undergone significant technical and athletic developments in recent years. This has led to an increased risk of injury supported by the observations inside Snowboard Germany, where, in particular, halfpipe injuries have increased in recent years, where 84.6% of injuries within the halfpipe team occurred on-snow. The most frequent injuries are concussions, followed by injuries to bones and ligaments of the lower extremities. These observations are also reflected in international injury reports (e.g., Flørenes et al., 2012). Our group has collected data from the German team consisting of over 1000 runs from elite athletes. This database contains >3000 aerials ranging from simple to complex jump elements (180-1260° rotations) with comprehensive biomechanical data. The purpose of this study was to study crashes resulting from unsuccessful jump landings to estimate head accelerations in cases where athletes did not stand the landing after the trick.

METHODS. Halfpipe snowboarding was assessed using three systems in combination. The center of mass (COM) positional data, speed, and acceleration were assessed using a wearable tracker system (Naos, Archinisis GmbH, Dürdingen, Switzerland) equipped with a GNSS (u-blox M10, fs = 1 Hz) and IMU sensor (ST ISM330DLC, fs = 208 Hz). For body movements, an IMU system (Xsens MVN Link, 240 Hz, Movella Technologies B.V., Enschede, Netherlands) was employed. Additionally, board loading and unloading, was measured by recording normal ground reaction forces (nGRF) using an insole system (loadsoles pro, sampling frequency = 200 Hz, novel GmbH, Munich, Germany). Time events were determined following Gorges et al. (2024). The study was approved from the University's Ethical Committee (no.: 037/2023) and the athlete provided informed written consent. Video recordings from all measurements were screened and jumps with unsuccessful landings were identified.

RESULTS. For this case study, one of the jump landings where the athlete caught the wrong edge was selected and head accelerations extracted (Figure 1).

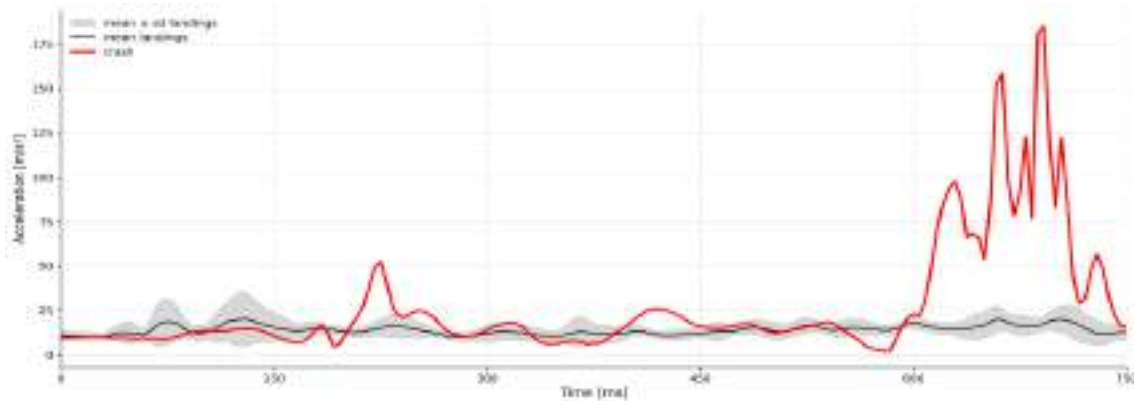


Figure 1. Resultant head accelerations from 7 trials matching the landing velocity of the unsuccessful landing were averaged (gray) and the fall (red) superimposed in red. Canting error at 600 ms, first peak of acceleration is the fall, with the first sharp peak indicating head contact with the snow.

DISCUSSION. When the head hit the surface maximum accelerations of appr. 18g were recorded. These were registered at the helmet as the IMU was taped to the surface of the headgear. Values can be considered critical in regard to head injuries while the accelerations transmitted to the head remain unknown (more cases added at ISSS).

CONCLUSIONS. These results raise concern about head accelerations during falls in training runs in halfpipe snowboarding. Further study is required to estimate accelerations transmitted to the head.

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Characterizing ambulation potential following acute traumatic spinal cord injury: a populational cohort study on 1209 patients

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Keywords: disability evaluation, walking, spinal cord injury, function recovery, prognosis

INTRODUCTION.

Prediction rules for ambulation after traumatic spinal cord injury (TSCI) are poorly adapted for individualized decision-making since it is impossible to predict with certainty. We propose a new paradigm of using a descriptive approach – rather than a predictive tool – to estimate the ambulation potential after TSCI

OBJECTI.

A retrospective study of 1209 patients from the Rick Hansen Spinal Cord Injury Registry was conducted. The **METHODS.**

A retrospective study of 1209 patients from the Rick Hansen Spinal Cord Injury Registry was conducted. The outcome was the level of outdoor walking 12 months following the SCI: dependent vs. limited vs. independent community ambulators. The actual ambulation outcomes were stratified by AIS severity grade, and by main phenotypes of individuals sharing similar baseline characteristics determined by classification tree analysis.

RESULTS.

The proportion of participants achieving independent, limited and dependent community ambulation were respectively 1.6%, 4.7% and 94% for AIS grade A SCI; 12%, 16% and 72% for AIS grade B; 28%, 23% and 50% for AIS grade C; and 65%, 24% and 11% for AIS grade D.

In addition to AIS grade, main phenotypes for ambulation outcomes were associated with lower extremity motor score (LEMS) and mechanism of injury for AIS grade B SCI, as well as LEMS and age for AIS grade C and D SCI.

CONCLUSIONS.

This study proposes a paradigm shift to describe rather than predict ambulation outcomes after TSCI, using a descriptive chart characterizing the potential for recovering community ambulation based on real outcomes observed in the general TSCI population, in order to facilitate estimating the ambulation potential early after TSCI.

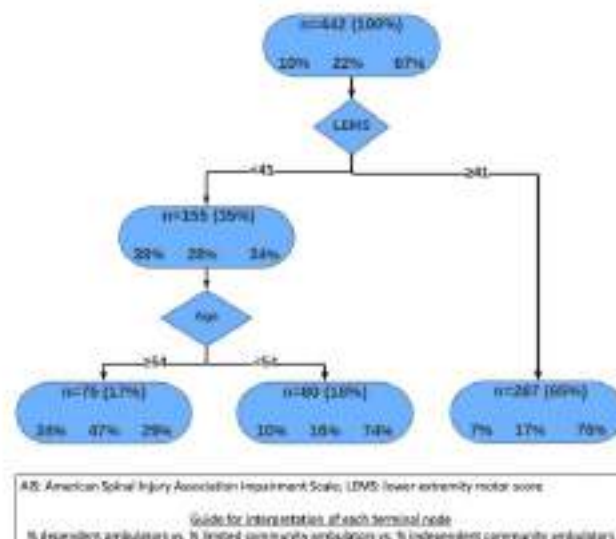


Figure 3 – Final tree for individuals with AIS grade D SCI. N.B.: Due to rounding of percentages, the total percentage can be lower than 100%.

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Landing Location Variation Due to Jump Geometry

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Keywords: Safety, Terrain park jumps, Jump kinematics, Takeoff Angle

INTRODUCTION. For terrain park jumpers, landing outside of the constructed landing zone increases the risk of injury. A quantitative understanding of the effects that influence landing locations can result in safer jumping events. In our previous work we studied the effect on landing location variability due to rider pop (jumping up or dropping down just prior to takeoff giving a positive or negative component to the takeoff velocity perpendicular to the takeoff surface). We found nearly all (99.9%) of jumpers had a pop speed between -2.2 m/s and +2.2 m/s, a result consistent with Hoholm's measurements of professionals taken at a slopestyle World Cup event [1]. In this work we examine the role of the takeoff angle on landing location variation.

METHODS. Using a physics-based model based on the pop value measurements previously studied, we examine the influence of the jump takeoff angle on the variation in landing location due to variation in both takeoff speed and pop value. For a specific example we consider a hypothetical medium-sized step-down jump shown in figure 1 and study the effect of the takeoff angle on the variation in landing location.

RESULTS. For the hypothetical jump considered with a 20° takeoff angle, the takeoff speed that results in landing at the center of the landing zone is 31.6 kph if there is no pop. The landing location changes by an average of .835 m per kph change in takeoff speed. For pop value, a variation of 3.0 m/s (-1.5 to +1.5 m/s) results in a variation of 3.76 m in the landing location. For a takeoff angle of 30°, the ideal takeoff speed changes to 30.2 kph with a variation in landing location of 0.806 m per kph in takeoff speed, a modest change. On the other hand, at a takeoff angle of 30° the same pop variation (-1.5 to +1.5 m/s) results in a landing location variation of only 0.99 m, a dramatic drop (see Figure 1).

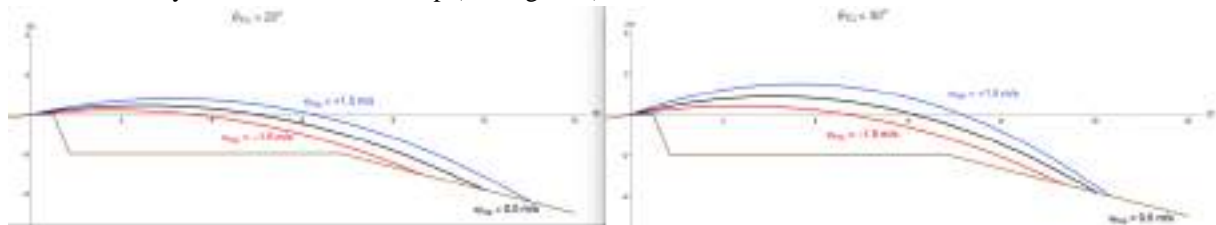


Figure 1: Trajectories showing landing location variation due to pop value variation of +/- 1.5 m/s.

DISCUSSION. The variation in the landing location due to pop variation is highly sensitive to the takeoff angle, while the change in landing variation due to takeoff speed is minimal. Further study reveals that the landing variation due solely to pop value variation vanishes if the takeoff angle is $\frac{1}{2} \text{ArcTan}(|\frac{x_L}{z_L}|)$, where (x_L, z_L) are the horizontal and vertical distances to the center of the designated landing zone.

CONCLUSIONS. Landing location variation is primarily influenced by pop and takeoff speed variation. One can design the jump takeoff angle to minimize landing location variation due to pop leaving takeoff speed the dominant factor determining landing location variability.

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Landing Location Variation Due to Pop Value Variation

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Keywords: Safety, Terrain park jumps, Jump kinematics, Pop effects

INTRODUCTION. Terrain parks have been an integral part of ski resorts for more than three decades, yet higher injury risk remains associated with jump features, particularly when riders land outside the constructed landing zone. Rider “pop” actions (jumping up or dropping down prior to takeoff) complicate the rider’s ability to gauge an appropriate approach speed. Shealy, et al. [1] found larger jump distance variability than expected solely due to takeoff speed variation, and McNeil [2] speculated that the anomalous landings seen by Shealy, et al. were due to pop. Hoholm [3] measured kinematic data at a World Cup slopestyle competition and found pop values between -2.3 and +2.2 m/s across all Pro participants. This study measured takeoff speed and pop values at two public ski resorts, which can be used to determine horizontal landing location variation due to pop alone.

METHODS. Over the 2024 ski season, we measured the trajectories of 948 jump events (including both skiers and snowboarders) at two public terrain parks using two VLP-32 Velodyne (San Jose, CA. 2019) lidar units. One unit was positioned uphill of the jump takeoff to capture approach kinematics, and one downhill of the jump takeoff to capture flight trajectories and landing locations. Data was collected across 13 days involving five jumps. The trajectories were analyzed to extract takeoff speed, pop value, and landing location.

RESULTS. Analysis of the lidar data revealed that 99.9% of jump events (947/948) demonstrated pop values fixed within +/- 2.2 m/s, consistent with the Hoholm results. In fact, 92.3% (875/948) fell within +/- 1.5 m/s. For the two larger jumps, where 349 jump events were measured, 67% (234/349) of the pop values were positive. For the three smaller jumps, 599 jumps were measured, and the pop values were evenly distributed, with 49.9% (299/599) events having positive pop. With this range of pop values, the variation in the horizontal landing location due to pop can be calculated. For a hypothetical medium-sized step-down jump (20° takeoff angle, 6.8 m deck, and 30° landing slope), the horizontal landing location changes by an average of 0.835 m per kph change in takeoff speed while the landing location changes by 1.25m per 1.0m/s change in the pop value. The sensitivity of these landing range deviations to changes in jump geometry is the subject of a separate study.

DISCUSSION. Takeoff speed is largely determined by the approach geometry and the rider’s actions and therefore can vary widely, which in turn widely varies the possible landing location. On the other hand, pop value in both professional and amateur contexts are highly constrained. These results suggest that the key to constraining variation in the landing location is constraining the takeoff speed.

CONCLUSIONS. Due to the limited range in pop values, constraining the takeoff speed can significantly reduce landing location variability increasing the likelihood of the rider landing in the constructed landing area.

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Biomechanical analysis of knee ligament loading during ski jump landing

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Keywords: ski jumping, landing, knee injury, mechanical loadings, finite element

INTRODUCTION. Ski jumping is a high-risk winter sport, and jump landings in recreational skiing are also associated with high impact forces, making the landing phase a critical moment for injury occurrence. During ski jump landings, the knee is the most frequently injured body region, accounting for over one-third of reported injuries, with many classified as severe time-loss injuries [1,2]. Ligament injuries, particularly anterior cruciate ligament (ACL) ruptures, are predominant and are associated with long rehabilitation periods and reduced return to pre-injury performance. Poorly controlled or crash landings are the main injury mechanisms; however, knee joint loading during ski jump landing remains insufficiently quantified. Improved understanding of landing-related knee loading is therefore essential for clarifying injury mechanisms and informing prevention strategies related to technique, training, and equipment design.

METHODS. The Total Human Model for Safety (THUMS) was used to simulate ski jump landing biomechanics (Fig. 1). The model was positioned in a representative landing posture using Oasys PRIMER based on literature data, with hip, knee, and ankle flexion angles of 107.7°, 108.1°, and 21.6°, respectively (Fig A). Vertical ground reaction force (GRF) pulses with a total duration of 200ms and a peak at 100ms were applied to both feet to represent landing impacts (Fig B). Peak force magnitudes ranged from 697.5 to 3487.5 N per foot, corresponding to approximately 0.9–4.5 body weights (BW). Knee joint loading was quantified using resultant forces and moments at femoral and tibial cross-sections near the knee, and ligament responses were assessed via von Mises stress and first principal strain in ACL and medial collateral ligament (MCL).

RESULTS. Axial force and flexion moment were the dominant knee joint loading components during landing (Fig C). Femoral and tibial axial forces ranged from 3539.4–4067.3 N and 1319.8–2290.5 N, respectively. Flexion moments ranged from 54.1–159.6 Nm at the femur and 184.7–346.0 Nm at the tibia. Ligament-level analysis showed peak first principal strains of 9.7–18.3% in the ACL and 3.7–4.6% in the MCL (Fig D), while von Mises stress ranged from 0.097–0.183 MPa for the ACL and 0.754–9.619 MPa for the MCL. ACL peak strain and stress increased consistently with increasing GRF, whereas MCL peak strain and stress were consistently localized near the femoral insertion.

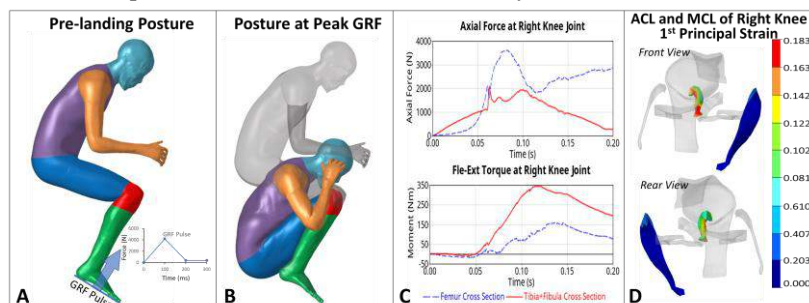


Figure - Finite element modeling of ski jump landing: A) Applying GRF at pre-landing posture; B) landing posture at peak GRF; C) Knee joint axial force and flexion-extension torque; D) Peak value of ACL and MCL 1st principal strain

DISCUSSION AND CONCLUSIONS. The simulated loading conditions indicate that increasing GRF (0.9–4.5 BWs per foot) progressively elevate ACL loading through combined axial compression and knee flexion, a mechanism known to promote anterior tibial translation. At higher impact levels, predicted ACL strains approached or exceeded published pre-failure strain values (~15.3%) [3], suggesting a potential risk of ACL rupture during high-load or poorly controlled landings. In contrast, MCL strains remained below reported failure thresholds (~6.3%) [3] across all simulated conditions, indicating a lower likelihood of isolated MCL rupture under predominantly vertical loading. These findings suggest that ski jump landing impacts within the upper range of measured forces may place the ACL at risk of injury, while MCL failure is less likely unless additional valgus or asymmetric loading is present.

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POLE LENGTH MODULATES CYCLE AND GROUND CONTACT TIME DURING SIMULATED UPHILL SKI MOUNTAINEERING

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Keywords: accelerometer, biomechanics, kinematics, performance, skiing, skimo

INTRODUCTION. Ski mountaineering, debuting at the Milano Cortina 2026 Winter Olympic Games, features greater pole length variability than trail running or traditional cross-country skiing. Previous studies have reported that pole length in ski mountaineering does not substantially affect physiological parameters such as heart rate, ventilation, oxygen consumption, or efficiency (Rauter et al. 2024). However, this does not preclude potential effects on technique or biomechanical parameters related to performance. Therefore, this study aimed to investigate the effects of different pole lengths on cycle time (CT) and ground contact time (GCT) during uphill treadmill walking.

METHODS. Eight ski-mountaineering athletes performed uphill walking on a treadmill (Rodby, Sweden). Ventilatory thresholds (VT1 and VT2) and the corresponding treadmill speeds were determined using an incremental test with a Cosmed K5 metabolic analyser (Cosmed, Italy). Participants then completed three trials using poles of different lengths: preferred, -5%, and +5%. Athletes were instrumented with two accelerometers (Dytran, USA) mounted on the skis and connected to a Dewesoft Dewe-43 analogue-to-digital converter (Dewesoft, Slovenia). CT and GCT were calculated using a custom-developed algorithm (Majerič et al. 2025). Each trial consisted of a 10-minute warm-up, followed by 5 minutes at VT1, a 2-minute passive recovery, and 5 minutes at VT2. Differences between pole lengths were analysed using a linear mixed-effects model. The study was approved by the relevant ethics committee.

RESULTS. Across all participants, approximately 3,400–3,700 GCT measurements and 1,600–1,900 gait cycles per pole condition were analysed at each intensity. At VT1, GCT was significantly shorter with short poles compared with the preferred length (-0.021 s, $p < 0.001$) and also differed significantly with long poles (-0.007 s, $p < 0.001$), with mean values of 0.93 ± 0.08 s, 0.95 ± 0.10 s, and 0.94 ± 0.08 s for short, preferred, and long poles, respectively. Short and long poles also resulted in a significantly lower CT compared with preferred (-0.036 s and -0.010 per cycle, both $p < 0.001$), respectively, with mean CT values of 1.41 ± 0.08 s, 1.45 ± 0.12 s, and 1.43 ± 0.10 s, respectively. At VT2, GCT was reduced with short poles (-0.004 s, $p < 0.001$) and increased with long poles ($+0.009$ s, $p < 0.001$), with corresponding mean values of 0.84 ± 0.07 s, 0.85 ± 0.08 s, and 0.85 ± 0.07 s. For CT, no difference was observed between short and preferred poles ($p = 0.070$), whereas long poles resulted in a higher CT compared with preferred poles ($+0.015$ s per cycle, $p < 0.001$), with mean values of 1.30 ± 0.10 s, 1.31 ± 0.11 s, and 1.32 ± 0.11 s, respectively.

DISCUSSION. The present findings demonstrate that deviations from the preferred pole length ($\pm 5\%$) systematically alter gait characteristics during uphill walking. Short poles consistently promoted shorter GCT and lower CT, particularly at VT1, suggesting a shift towards a more dynamic stepping pattern. At higher intensity (VT2), the effects on CT were attenuated, indicating that increasing physiological demand may constrain gait modulation, while GCT remained sensitive to pole length manipulation.

CONCLUSIONS. Short pole lengths appear to facilitate shorter cycle and ground contact times during uphill walking, whereas long poles tend to induce distinct time responses. These findings highlight pole length as a relevant external constraint influencing locomotor mechanics across exercise intensities.

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Comparing Snowsport Helmet Impact Performance

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Keywords: Snowsport helmets, Helmet rating systems, Oblique testing, Concussion

INTRODUCTION. Head injuries account for approximately 15% of snowsport-related injuries, yet they comprise more than 40% of cases treated at trauma centers [1–3]. Although snowsport helmets reduce head injury risk by 21–45% [4], current U.S. certification standards are pass/fail tests intended to prevent catastrophic injury and do not incorporate rotational kinematics or fully represent the oblique head impacts common in snowsports. Consequently, there is a critical need for a real-world-informed evaluation framework that can differentiate helmet performance and estimate relative concussion risk. This study aimed to implement a real-world-informed test methodology capable of differentiating helmet performance and estimating relative concussion risk.

METHODS. Real-world snowsport head impact videos informed laboratory testing using an oblique drop tower with an instrumented 50th percentile NOCSAE headform. 48 helmet models (4 samples per model) were tested at one resultant velocity (6.7 m/s), two anvil angles (35° and 55°), three impact locations (front, side, rear boss), and two trials per configuration. Each model was impacted 12 times, for a total of 576 tests. Linear acceleration and rotational velocity were measured at 20 kHz. Concussion risk was estimated using a multivariate injury risk function incorporating peak linear acceleration (PLA) and peak rotational velocity (PRV). The average injury risk [R] per impact condition was used to compute a single Summation of Tests for the Analysis of Risk (STAR) value for each helmet model, accounting for equal exposure across locations and velocities.

$$\text{SnowsportSTAR} = \sum_{L=1}^6 \sum_{V=1}^2 E(L, V) * R(a, \omega)$$

RESULTS. Normal velocity influenced PLA and injury risk ($p < 0.0001$), with high normal velocity impacts producing 40.5% greater injury risk than high tangential conditions. Impact location influenced PRV ($p < 0.0001$), with front impacts producing the highest risk and side impacts the lowest. Average injury risk across helmet models was $51.1 \pm 29.7\%$, with an 88.4% reduction in risk between the best- and worst-performing helmets. STAR values ranged from 0.36 to 3.10, demonstrating meaningful differentiation among certified helmets.

DISCUSSION. This methodology provides a reproducible laboratory framework that incorporates rotational kinematics and oblique impacts representative of real-world snowsport crashes. Results demonstrate variability in concussion risk reduction across commercially available helmets despite all meeting current certification standards. The velocity component contributed more strongly to risk than the impact location, underscoring the importance of evaluating both normal and tangential impact dynamics. Further, the helmet shell's frictional properties influenced rotation, whereas glossy helmets performed better than matte helmets.

CONCLUSIONS. A real-world-informed oblique impact testing protocol can meaningfully differentiate snowsport helmet performance beyond pass/fail standards. The Snow Sport STAR framework provides a consumer-facing rating system that estimates relative concussion risk and may drive design improvements to enhance athlete safety.

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Considering inclusive sporting goods for snow sport safety

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Keywords: Engineering, equipment, protection

INTRODUCTION. Safety assessments and devices often do not account for a broad and diverse demographic of users. Well-known examples include the traditionally male-centric (androcentric) anthropometric test devices in automotive safety tests that do not represent children and women. In a similar manner, the condition, design, and general suitability of sporting goods will influence snow sport safety. Sporting goods includes products like clothing, equipment, wearable technology (sensors), and protective devices. The latter includes personal devices worn by snow sports participants, such as body padding, helmets, and wrist protectors, and padding positioned by ski patrollers to protect against collisions with fixed objects (Dorsemaine et al., 2023). For sporting goods to have a positive, meaningful, and widespread impact on snow sports safety, as well as performance and enjoyment, it is imperative that they cater for the needs of all potential participants.

The Institution of Mechanical Engineers (IMEchE) recently published the policy report: “*Sustainable, inclusive, innovative: the role of engineering in sport*” (Allen et al., 2023). The report highlights a gap in the current approach to developing sporting goods. This gap has led to inequalities in sporting goods for participants, which is likely to influence snow sport safety.

METHODS. This talk will summarise the approach, findings, and recommendations of the IMechE report (Allen et al., 2023) before discussing the implications for snow sports safety.

RESULTS. The report highlights factors related to inclusivity and potential barriers to sport participation. Alongside a lack of appropriate sporting goods, these include age, disability, health, knowledge and guidance, religion, sex and gender, and social economic background. The report notes that despite these factors, sporting goods should ideally work well for a diverse range of participants and meet their needs. It also highlights how developments in assistive devices and associated technologies are helping more disabled people engage in sport, while discussing the growing need to cater for the increasing diversity of participants with varying expectations and needs. The role of wearable technology in detecting injury likelihood from an incident, particularly concussion, is also noted, as is the importance of using appropriate and diverse datasets when developing sporting goods. The recommendations to address these issues include, more specialist test facilities, increased transfer of technology from elite to recreational sport, an “open science” approach to data sharing, and transdisciplinary collaboration.

DISCUSSION. The IMechE report has clear and direct implications for snow sport safety. For example, ill-fitting or otherwise inappropriate sporting goods can compromise the safety of the user and other participants. It can reduce the user’s performance and safety in various ways, such as by hindering their confidence, control, hearing, vision, and physical or thermal comfort. A key step in making sporting goods more suitable for a diverse range of participants is to ensure that they are appropriately represented in research studies (Mears et al., 2024). This extends to research studies and safety standards focussed on testing sporting goods. Therefore, all protocols, simulations, and human body surrogates should encompass the broad range of potential snow sports participants.

CONCLUSIONS. Applying a more inclusive approach to the development of snow sports goods could enhance safety, although further work is needed to gain a better understanding of the current situation.

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Ski Area Padding: Examining the Potential to Mitigate Injury Risk at Beginner Speeds

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Keywords: Ski Area Padding, Head Injury, Torso injury, Spine injury

INTRODUCTION. Ski areas in the United States (US) often place padding on manmade structures such as snowmaking equipment and chairlift towers. This padding serves generally two purposes: (1) primarily to make these objects more visible (to act as a warning, helping skiers avoid collisions) and (2) secondarily to act as an impact attenuation system to reduce the likelihood of injuries in the event of a collision [1]. Prior work that examined the impact attenuation potential showed that US ski area padding cannot prevent all head and spine injuries during direct, axial impacts, even at low speeds [2]. This research project is an expansion of the previous work that examines additional body orientations at impact.

METHODS. A custom-made pendulum impactor system was made using an instrumented 50th-percentile-male Hybrid-III anthropomorphic testing device (ATD). The ATD weighed 76 kg including ski clothing, boots, and a helmet. The ATD was instrumented with head accelerometers, a chest deflection sensor, and a chest accelerometer. For each test, the ATD was raised 1.7 m, released, and swung into either: (1) a 10-cm diameter snowmaking pole or (2) a 25-cm diameter chairlift tower with ladder. Twenty padding models commonly used at US ski areas were evaluated, with each pad applied only to its intended structure(s). Tests were conducted with the ATD in either a vertical orientation (simulating an upright skiing stance) or horizontal orientation (simulating a person sliding chest first into a rigid object). The ATD impact speed was measured with a laser speed trap. For each test trial, the metrics related to head and chest injury were measured. The peak head acceleration, peak head angular velocity, the 15-ms head injury criterion (HIC₁₅), peak chest deflection, 3-ms chest acceleration, and peak viscous criterion (VC_{max}) were determined. The results were compared to the injury assessment reference values (IARVs) [3].

RESULTS. 152 test trials were conducted with a mean impact speed of 20.8 (± 0.8) kph; for tests with the ATD in a vertical orientation, 73 test trials were conducted with a mean impact speed of 21.1 (± 0.9) kph. When compared to impacts with an unpadded pole, typical ski area padding reduced significantly the peak head accelerations, peak angular velocity, HIC₁₅ (see Figure 1) for impacts in the vertical orientation. The sternal deflection, 3-ms chest acceleration, and VC_{max} response were mixed, with some pads lowering the peak values and other having little influence on the results; for example, padding did not influence the peak sternal deflection for vertical impacts (see Figure 1 below that shows the data for the vertical orientation). In general, for the horizontal impacts padding reduced significantly the chest injury metrics, but not the head injury metrics.

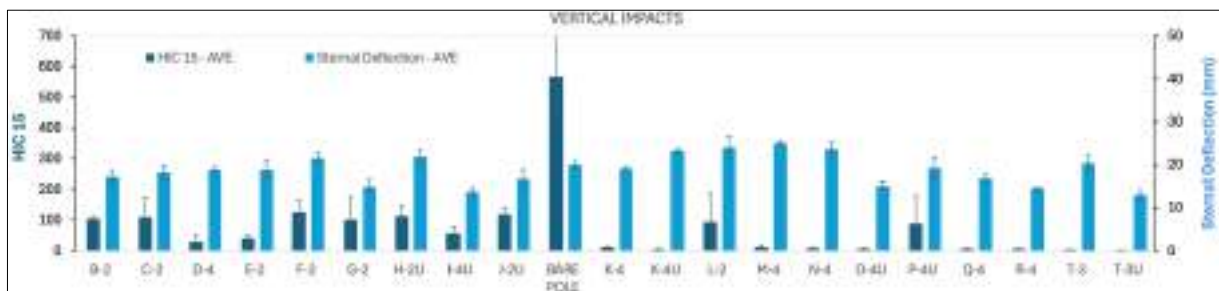


Figure 1. HIC₁₅ and sternal deflection response for tests using an upright skiing orientation (IARVs: 700 and 50 mm)

DISCUSSION. Previous research indicated that ski area padding may not reduce the likelihood of cervical spine injury in headfirst impacts with a rigid object, even at speeds that were below those of typical beginners [2]. The current tests expand on that work by examining impacts with other orientations. For the impacts tested that were at (or below) speeds typical of beginners in the US [4], padding used at US ski areas reduced the likelihood of head injury and chest injury compared to impacts with a bare pole and kept the metrics below the associated IARVs.

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Pilot Study on the Effectiveness of Deceleration Nets for Falls from Chairlift

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Keywords: Deceleration Nets, Chairlift Fall, Unseated Passenger

INTRODUCTION. Ski areas in the United States (US) use chairlifts to transport patrons up the mountain. While falls from chairlifts are rare, it is possible for passengers to become unseated and fall [1]. One method of emergency arrest for an unseated passenger is the use of a deceleration net, similar to those used by firefighters until the early-1980s in the US. To the authors knowledge, there have been no scientific studies on deceleration nets and their efficacy to reduce the likelihood of injury for a falling individual. This study provides a laboratory model to measure the capabilities and limitations of using a deceleration net.

METHODS. Four, male participants consented (IRB No. GEAR2307) to hold a 2.4-meter diameter, solid-vinyl ski area deceleration net and attempt to prevent a dropped mass from contacting the ground. Each pair of nylon strap handle locations on the net were instrumented with a custom load cell apparatus to measure the tensile force applied to the net by each person. A force plate was placed under the net to measure the ground impact force, should the participants fail to fully catch the drop mass. The mass and drop height were varied throughout testing. For each test, the pre-fall potential energy of the drop mass was calculated with respect to the ground, the peak forces applied by the participants were determined, and the peak load on the ground force plate was ascertained (when applicable).

RESULTS. The participants were unable to prevent ground contact when the initial potential energy of the dropped mass was 790 J or greater. At 790 J (~23 kg at ~3.5 m) of potential energy, the mass contacted the force plate and produced ~180 N of peak force. At 1,185 J (~34 kg at ~3.5 m) of potential energy, the ground impact force increased to ~11,500 N – this is in the range that could produce serious injury. In trials where the dropped mass contacted the ground, the peak tensile forces applied to the deceleration net by the participants did not increase as initial potential energy of the drop increased (see Figure 1 below).

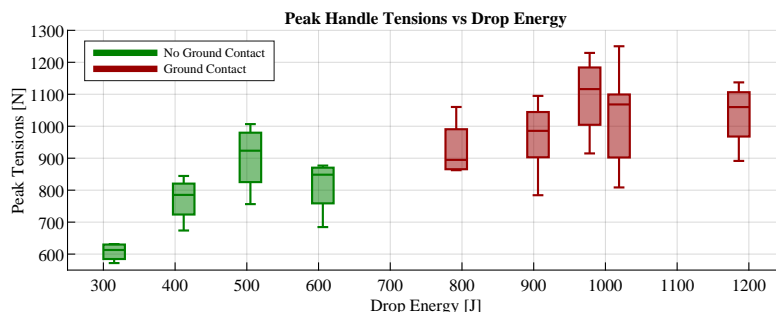


Figure 1. Max handle tension applied by each participant while varying drop height and mass

DISCUSSION. The plateau of peak handle tension suggests that the four participants reached a maximum amount of resistive force; they could not apply additional loads to the deceleration net to keep the mass from contacting the ground. There may be a limit to the energy they can attenuate through the deceleration net. If further testing shows similar results, the results could provide guidance on when the use of a catch net may be beneficial for chairlift rescues.

CONCLUSIONS. This test setup allows the measurement of forces applied to a deceleration net by rescuers to assess the potential efficacy of ski area deceleration nets. Even under ideal laboratory conditions, ski area deceleration nets have a limited ability to reduce the energy and force at contact. Additional testing will be conducted to understand better the potential merits and limitations of ski area deceleration nets.

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SPORSA: Safety and Tracking Platform for Mountain Sports

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Keywords: safety hub; crash detection; machine learning

INTRODUCTION. Mountain sports such as alpine skiing, snowboarding, and mountain biking involve high speeds, complex terrain, and rapidly changing environmental conditions, resulting in a high risk of crashes and delayed emergency response. Safety monitoring and communication in these sports remain fragmented, reactive, and often dependent on individual devices or manual reporting. SPORSA addresses these challenges with a connected safety system originally developed and proven in road cycling, a sport with dense group dynamics and high crash rates. Building on this foundation, SPORSA is now being upscaled to mountain sports, where safety challenges are often amplified by terrain, visibility, and remoteness.

METHODS. The SPORSA device integrates a GPS module and an Inertial Measurement Unit (IMU) for continuous positioning (tracking) and to detect crashes, near-misses, and abnormal movement patterns using machine learning. A device-to-device scanner is used to detect nearby devices and provide redundancy when GPS or connectivity quality degrades (e.g., forests) and allows for peer-to-peer functionalities. The device establishes a two-way communication stream over a low power LTE-M network and can alert users of upcoming high-risk zones through integrated LEDs, vibration or buzzer sounds. The accompanying dashboard uses an interactive map as a central communication platform. Safety-related Points of Interest (POIs) are generated automatically based on real-time sensor and location data, and can be supplemented by race officials, ski patrol, or mountain rescue teams.

RESULTS. Field tests and user workshops conducted during the road cycling validation phase demonstrated that SPORSA can detect crashes, near-incidents, and abnormal peloton dynamics, while providing synchronized safety information to all participants. Riders and coaches reported improved situational awareness and reduced uncertainty during chaotic race moments. When translated to mountain sports, the same system enables:

- Early detection of falls and near-miss incidents on ski slopes, bike trails, and mountain routes
- Automatic visualization of incident severity, inferred from IMU readings and trajectory data
- Location-based warnings to athletes approaching hazardous zones such as blind corners, icy sections, narrow trails, or avalanche-prone areas
- Faster and more informed response from medical and rescue services through live incident mapping

Unlike existing consumer safety solutions (e.g., smartwatch or smartphone-based alerts), SPORSA does not rely on user-initiated sharing, smartphone connectivity, or isolated individual monitoring. Instead, it utilized a low power network and provides context-aware safety insights, a critical requirement repeatedly emphasized by stakeholders.

DISCUSSION AND CONCLUSION. Current safety systems in mountain sports largely focus on the individual athlete and are often reactive rather than preventive. Many rely on smartphones, which are vulnerable to battery drain (since it's a general-purpose device) and connectivity loss in alpine environments. Moreover, these systems rarely account for near-incident data, despite evidence that near-misses are predictors of future accidents [1]. The SPORSA platform builds on this and enables safer, more transparent, and better-informed mountain sport experiences.

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The Influence of Environmental and Human Factors on Inbounds Skiing Accidents at a Representative Alpine Resort in Western North America

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Keywords: skiing, human factors, environmental factors, mixed methods

The ski industry is a significant cultural and economic cornerstone of Western Canada, with over 120 resorts attracting more than 9.5 million skier visits annually and contributing an estimated \$2.67 billion to the regional economy (CWSAA, 2025). Despite its popularity, alpine skiing remains a high-participation, high-risk sport where thousands of individuals sustain injuries each season. While historical injury rates have declined from approximately five to between 2.2 and 4.6 per 1,000 skier days due to advances in equipment, specifically ski boot-binding systems, the complexity of modern accidents remains multifaceted (Natri et al., 2012; Dickson & Terwiel, 2021). Current research suggests that while most accidents involve human error, these errors are inextricably linked to a "complex web of interactions" between psychological, behavioral, and environmental elements (Yang & Fan, 2021; Fawver et al., 2020).

This research seeks to determine how human factors (age, ability level, helmet use) and environmental variables (daily snowfall, temperature, visibility, run difficulty, and crowding) interact to influence the rate and severity of in-bounds incidents. The study employs a retrospective, explanatory sequential mixed-methods design. Part 1 consists of a quantitative analysis of eight seasons (2017–2025) of 8,000 historical patient care reports and environmental data. Machine learning (ML) models will be used to identify predictive patterns and non-linear interactions between variables such as skier demographics, weather conditions, and terrain difficulty. By using ML, the study seeks to uncover hidden correlations that influence accidents. Part 2 utilizes semi-structured interviews with Subject Matter Experts (SMEs), including ski patrollers and mountain operations staff, to help to add context to the findings in Part 1. These expert insights are critical for understanding the "on-the-ground" reality of risk perception and behavior that quantitative data alone cannot capture (Fawver et al., 2020). Analysis is ongoing, and results are pending.

By integrating these data sources, this project seeks to bridge the gap between retrospective injury reporting and the real-time environmental influences that lead to accidents. Findings are expected to provide a system-level understanding of skiing safety, moving beyond individual error to examine organizational and environmental influences. This research will contribute to both operational resilience and visitor wellbeing, providing a foundation for evidence-based strategies in skier education and resort safety policies.

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RECYCLE OF END-OF-LIFE SAFETY EQUIPMENT FOR SKI RESORTS

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Keywords: recycling, end-of-life, circular economy, safety mattresses, nets, poles

INTRODUCTION. Ski resort safety equipment used to protect skiers during the skiing activity (mattresses, nets and poles) must be changed after a certain number of seasons due to impacts during use and degradation that can occur due to the exposure to cold climates and UV light. Currently, all the ski resort safety equipment is disposed of in landfills due to the lack of recycling methods, which represents a significant environmental concern. For this reason, we have developed a set of recycling processes to obtain new materials to be re-used in the same or similar applications.

METHODS. Safety mattresses have been separated from their cover and ground in a blade grinder with 5 mm grids. The grinded foam has been agglomerated with a rebonding process with 10% w/w of a polyurethane pre-polymer as a binder. The rebounded foam has been compacted under pressure for 12 hours to obtain a proper adhesion of the ground foam. 10 mm thickness samples have been cut from the foam block and encapsulated in a standard protective layer used for safety mattresses. Impact tests have been performed on mattresses using the ISO EN 12503-1 norm used for sport mattresses, by measuring the peak deceleration at 100J impact energy. Mechanical recycling of nets (made of polyethylene, PE) and of poles (made of polycarbonate, PC) was performed by grinding the end-of-life nets and poles with a blade grinder with a 3 mm grid and then injection molded using a BabyPlast 6/12 injection molding machine. Tensile testing of recycled thermoplastic polymers was performed according to ISO 527, while impact tests have been performed according to ISO 180 on injection molded specimens at 23°C and at -20°C.

RESULTS. The rebonding process produced samples with a density of approximately 80 kg/m³ that is higher than that of the starting foam (20 Kg/m³). For this reason, the recycled foam layers have been cut with holes to reduce the density of the final mattress to approximately 40 kg/m³. The impact tests have showed a peak deceleration of 40 g that is higher than that obtained testing a standard foam mattress (25 g). The recycled PC from the poles has an elastic modulus of 2400 MPa, an elongation at break of 80% and a tensile strength of 70 MPa with values that are not significantly different from those of the virgin material. The impact strength (80 J/m² at -20°C) was also not significantly different from that of the virgin material. The recycled PE of the nets showed a modulus of 1200 MPa, a tensile strength of 30 MPa and an elongation at break of 670 % indicating that the material is suitable for the preparation of new fibers for nets.

DISCUSSION. The impact tests on the recycled foam indicate that the recovered material provides a deceleration of 40 g after an impact of 100 J which is, however, significantly higher with respect to that of the standard virgin foam. Further tests are needed to optimize the foam cuts and the sample thickness to reach the same decelerations. The tensile and impact testing on the recycled thermoplastic materials used for poles (PC) and nets (PE) show that neither use nor recycling process affect the mechanical properties of the materials that thus can be efficiently recycled and reused in the same applications.

CONCLUSIONS. We have demonstrated that the materials of mattresses, nets and poles can be efficiently recycled to be reused in similar applications thus decreasing their environmental impact. This work constitutes the first proof of concept for the recycling of end-of-life safety equipment toward industrial-scale implementation.

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Considering inclusive sporting goods for snow sport safety

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Keywords: Engineering, equipment, protection

INTRODUCTION. Safety assessments and devices often do not account for a broad and diverse demographic of users. Well-known examples include the traditionally male-centric (androcentric) anthropometric test devices in automotive safety tests that do not represent children and women. In a similar manner, the condition, design, and general suitability of sporting goods will influence snow sport safety. Sporting goods includes products like clothing, equipment, wearable technology (sensors), and protective devices. The latter includes personal devices worn by snow sports participants, such as body padding, helmets, and wrist protectors, and padding positioned by ski patrollers to protect against collisions with fixed objects (Dorsemaine et al., 2023). For sporting goods to have a positive, meaningful, and widespread impact on snow sports safety, as well as performance and enjoyment, it is imperative that they cater for the needs of all potential participants.

The Institution of Mechanical Engineers (IMEchE) recently published the policy report: “*Sustainable, inclusive, innovative: the role of engineering in sport*” (Allen et al., 2023). The report highlights a gap in the current approach to developing sporting goods. This gap has led to inequalities in sporting goods for participants, which is likely to influence snow sport safety.

METHODS. This talk will summarise the approach, findings, and recommendations of the IMechE report (Allen et al., 2023) before discussing the implications for snow sports safety.

RESULTS. The report highlights factors related to inclusivity and potential barriers to sport participation. Alongside a lack of appropriate sporting goods, these include age, disability, health, knowledge and guidance, religion, sex and gender, and social economic background. The report notes that despite these factors, sporting goods should ideally work well for a diverse range of participants and meet their needs. It also highlights how developments in assistive devices and associated technologies are helping more disabled people engage in sport, while discussing the growing need to cater for the increasing diversity of participants with varying expectations and needs. The role of wearable technology in detecting injury likelihood from an incident, particularly concussion, is also noted, as is the importance of using appropriate and diverse datasets when developing sporting goods. The recommendations to address these issues include, more specialist test facilities, increased transfer of technology from elite to recreational sport, an “open science” approach to data sharing, and transdisciplinary collaboration.

DISCUSSION. The IMechE report has clear and direct implications for snow sport safety. For example, ill-fitting or otherwise inappropriate sporting goods can compromise the safety of the user and other participants. It can reduce the user’s performance and safety in various ways, such as by hindering their confidence, control, hearing, vision, and physical or thermal comfort. A key step in making sporting goods more suitable for a diverse range of participants is to ensure that they are appropriately represented in research studies (Mears et al., 2024). This extends to research studies and safety standards focussed on testing sporting goods. Therefore, all protocols, simulations, and human body surrogates should encompass the broad range of potential snow sports participants.

CONCLUSIONS. Applying a more inclusive approach to the development of snow sports goods could enhance safety, although further work is needed to gain a better understanding of the current situation.

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Epidemiological Analysis of Wrist and Forearm Injuries in Skiing and Snowboarding A sixteen years' experience in Greece

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Keywords: wrist, ski, snowboard, injuries, epidemiology

INTRODUCTION. Injuries of wrist and forearm are among the most common upper-limb injuries in Snowsports worldwide, imposing a considerable clinical and operational burden among athletes and healthcare services. 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, 5614 injured Skiers and Snowboarders were recorded, at Parnassus ski resort, using a multivariable protocol, over 16 winter seasons (2007- 2025). Of those, 709 (12.6%) sustained a wrist/forearm injury. General and sport-specific characteristics (e.g., age, sex, participation in lessons) were collected. A control group of 846 uninjured athletes was randomly sampled on the slopes using the same protocol. Injury incidence was expressed as IPTSD (injuries per 1,000 skier-days) and MDBI (mean days between injuries), with exposure estimated from total tickets sales. Risk factors were examined with multivariable logistic regression, effect heterogeneity with interaction terms and likelihood ratio testing, and injury type/severity plus within-case predictors were assessed among wrist-injury cases.

RESULTS. The overall wrist injury incident was 0,5 injuries per 1000 skier days (IPTSD) showing a slight decline over time. The MDBI was 4.426 days for skiers and 866 days for snowboarders. In the multivariable model, snowboarding in general was strongly associated with increased odds of wrist injury compared with skiing (OR 5.29, 95% CI 4.15–6.74; $p=2.09\times 10^{-41}$), while males have lower possibility than females (OR 0.78, 95% CI 0.62–0.98; $p=0.030$). According to age, youth (≤ 17 years) had higher adjusted odds of wrist/forearm injury compared with adults (≥ 18 years) (OR 1.85, 95% CI 1.46–2.35; $p=4.49\times 10^{-7}$). Importantly, among adults only, snowboarding remained a strong independent risk factor (OR 4.99, 95% CI 3.74–6.65; $p=6.70\times 10^{-28}$), and adult females had higher odds than adult males (OR 1.48, 95% CI 1.13–1.94; $p=0.0043$), confirming that the association was not confined to pediatric populations. Interaction analyses showed that youths had higher odds of wrist/forearm injury than adults in both sports, with the association notably stronger in snowboarders (OR 2.46, 95% CI 1.68–3.60; $p=3.75\times 10^{-6}$) than in skiers (OR 1.51, 95% CI 1.09–2.07; $p=0.0119$). Among younger males, risk patterns differed by activity: boys aged 4–10 years who snowboarded had markedly higher odds of wrist injury than same-age skiers (OR 10.59, 95% CI 2.94–38.16; $p=0.000306$), whereas among male skiers the odds rose progressively with age (11–14 vs 4–10: OR 3.99, 15–17 vs 4–10: OR 5.54), suggesting a distinct age-related risk gradient specific to skiing. Wrist injuries were most commonly fractures (53.46%), followed by strains (24.96%). Males had lower odds of fracture than females (OR 0.65, 95% CI 0.47–0.89; $p=0.00793$), and snowboarding was associated with a higher fracture risk than skiing (OR 1.98, 95% CI 1.38–2.83; $p=0.000183$). Most injuries were isolated (92.0%), and when concomitant injuries occurred (8.0%), the shoulder was the most frequent additional site.

DISCUSSION AND CONCLUSIONS. Across multiple winter seasons, wrist injuries are a notable cause of medical incidents. Risk was markedly higher in snowboarders and differed by age and sex, with younger participants appearing particularly vulnerable. Fractures predominated, supporting targeted, activity-specific education for prevention.

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High Rates of Return to Sport After Arthroscopic Shoulder Stabilization in Elite Winter Sports Athletes

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Keywords: arthroscopic Bankart repair, shoulder injuries, return to sports, winter sports, ski, ice hockey

INTRODUCTION. Elite winter sports athletes are at high risk of shoulder instability due to high-energy injury mechanisms involving speed, falls, and limited braking capacity. Although the epidemiology of shoulder injuries in winter sports has been well described, postoperative outcomes following arthroscopic stabilization—particularly return-to-sport outcomes—remain poorly characterized in elite and professional winter sports athletes. In this study, we aimed to evaluate functional outcomes, return-to-sport rates, and athlete-perceived performance following primary arthroscopic shoulder stabilization in elite winter sports athletes.

METHODS. Elite winter sports athletes who underwent primary arthroscopic shoulder stabilization between 2010 and 2024 were retrospectively identified. Functional outcomes were assessed using the American Shoulder and Elbow Surgeons (ASES) and Rowe scores preoperatively and at final follow-up. Return-to-sport status, duration of continued elite-level participation, and recurrent instability were recorded. Athletes with limited clinical follow-up completed structured interview-based questionnaires assessing return to sport and perceived impact of surgery on performance and confidence. This study was approved by the International Review Board of Konkuk University.

RESULTS. Sixteen athletes were included after exclusion of two lost to follow-up. Mean ASES scores improved significantly from 62.3 ± 15.5 preoperatively to 94.5 ± 12.2 postoperatively ($p < 0.001$), and mean Rowe scores improved from 52.8 ± 20.7 to 95.0 ± 12.2 ($p < 0.001$). Fifteen athletes (93.8%) returned to competitive sports, with one athlete transitioning to a lower-risk sport. Two athletes (12.5%) reported a perceived negative impact of surgery on performance. Recurrent shoulder dislocation occurred in three athletes (18.8%); two returned to sport with nonoperative management, and one underwent revision stabilization. The mean duration of continued elite-level participation after surgery was 5.2 ± 3.8 years, with four athletes remaining actively competitive at final follow-up.

DISCUSSION. The principal finding of this study was that elite winter sports athletes demonstrated favorable functional outcomes and high rates of return to competitive sport following primary arthroscopic shoulder stabilization. Significant improvements were observed in both ASES and Rowe scores at final follow-up, and the majority of athletes were able to resume elite-level competition without a perceived reduction in confidence. Furthermore, the mean duration of continued elite-level participation after surgery was more than five years, with four athletes continuing to actively compete at the time of final follow-up, underscoring the potential durability of arthroscopic stabilization in winter sports athletes.

CONCLUSIONS. Arthroscopic shoulder stabilization procedures in winter sports athletes result in favorable outcomes in terms of shoulder function, return-to-sport, and self-perceived confidence.

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Clavicle Fractures in Recreational Skiing and Snowboarding: Mechanisms of Injury and Injury Patterns

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Keywords: clavicle fracture, recreational skiing, snowboarding, injury mechanism, injury pattern

INTRODUCTION. Participation in recreational skiing and snowboarding has increased steadily over recent decades, accompanied by a relative rise in upper-extremity injuries.^{1,2} Among shoulder girdle injuries, clavicle fractures are common; however, detailed analyses focusing on fracture patterns and associated shoulder injuries in recreational participants remain limited.¹

METHODS. A retrospective descriptive analysis was performed on recreational skiers and snowboarders who sustained clavicle fractures. Patient demographics, injured side, fracture location, Robinson classification for midshaft fractures when documented, treatment modality, and associated shoulder injuries were reviewed and analyzed.

RESULTS. A total of 155 patients were included, with a mean age of 27.3 years. Male patients accounted for 92.9% of cases, followed by female patients (6.5%). Injuries occurred more frequently on the left side (63.9%) than on the right (36.1%).

Midshaft fractures were the most common fracture pattern (84.2%), followed by distal clavicle fractures (15.8%). Among midshaft fractures with documented Robinson classification, type 2B2 was most frequent, followed by 2B1 and 2A1 patterns.

Surgical treatment was performed in 127 patients (81.9%). Associated shoulder injuries, including acromioclavicular or coracoclavicular ligament injuries, were identified in 6 patients (3.9%).

DISCUSSION. The findings demonstrate that clavicle fractures sustained during recreational skiing and snowboarding predominantly affect young male participants and most frequently involve the midshaft of the clavicle.^{1,3} Despite the high rate of surgical treatment, concomitant shoulder injuries were uncommon, suggesting that the majority of these injuries occur as isolated clavicle fractures rather than part of complex shoulder trauma.

CONCLUSIONS. Clavicle fractures in recreational skiing and snowboarding most commonly occur in young male patients and primarily involve the midshaft of the clavicle. Although surgical management is frequently required, associated shoulder injuries are relatively rare.

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Epidemiology and Injury Patterns of Traumatic Shoulder Dislocation in Skiing and Snowboarding: A Multicenter Tertiary Hospital–Based Study in Korea

Background

Skiing and snowboarding are popular winter sports associated with a high risk of upper extremity injuries, particularly traumatic shoulder dislocation. However, comparative data on injury mechanisms, bony lesion patterns, and treatment outcomes between skiing- and snowboarding-related shoulder dislocations remain limited.

Purpose

To compare epidemiologic characteristics, injury patterns, and treatment outcomes of traumatic shoulder dislocation related to skiing and snowboarding using multicenter tertiary hospital data in Korea.

Methods

This retrospective multicenter study included patients who presented to tertiary referral hospitals in Korea with traumatic shoulder dislocation sustained during skiing or snowboarding over a 5-year period. Patients were divided into ski and snowboard groups. Demographics, injury mechanisms, associated injuries, bony lesions (bony Bankart, glenoid defect, and glenoid track status), and treatment strategies were analyzed. Outcomes were compared between first-time and recurrent dislocations, as well as between conservative and surgical treatments.

Results

Snowboarding-related dislocations were more frequently associated with fall or rolling mechanisms, whereas skiing-related injuries were more commonly related to slip-down mechanisms. The snowboarding group demonstrated a higher incidence of associated injuries and bony lesions, including bony Bankart lesions and off-track glenoid lesions, compared with the skiing group.

In first-time dislocations, conservative treatment showed variable success, with a subset of patients requiring subsequent surgical stabilization. Surgical treatment demonstrated a low rate of redislocation. In recurrent dislocations, conservative treatment was associated with a higher failure rate, whereas surgical stabilization resulted in more favorable stability outcomes.

Conclusion

Skiing- and snowboarding-related shoulder dislocations differ significantly in injury mechanisms and bony injury patterns. Snowboarding injuries tend to be associated with more complex bony pathology. Treatment outcomes differed according to dislocation history, with surgical treatment providing more reliable stability in recurrent dislocations. These findings may help guide sport-specific injury prevention strategies and treatment decision-making.

Sport-Specific Concomitant Injury Patterns in Acute Non-Contact ACL Injuries: A Comparative Study of Skiing and Soccer

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Keywords: Anterior cruciate ligament injury, skiing, soccer, bone contusion, concomitant injury

INTRODUCTION. Non-contact anterior cruciate ligament (ACL) injuries are frequently accompanied by damage to the subchondral bone, meniscus, and collateral ligaments. These concomitant injury patterns may vary significantly by sport, reflecting distinct underlying biomechanical mechanisms. This study aimed to characterize concomitant injuries in acute non-contact ACL injuries and to compare these patterns between skiing and ground-based sports such as soccer to elucidate sport-specific injury mechanisms.

METHODS. This retrospective study, approved by the institutional review board, analysed patients with acute non-contact ACL injuries who underwent arthroscopic reconstruction between 2014 and 2024. The study population consisted of two cohorts: skiing-related injuries (n=131) and soccer-related injuries (n=156). Magnetic resonance imaging (MRI) and arthroscopic findings were analyzed to determine the location and severity of concomitant injuries. To quantify the severity of bone bruising, the bone contusion ratio (BCR) was calculated as the maximal width of the contusion area at the subchondral level divided by the maximal width of the lateral femoral condyle (LFC).

RESULTS. Bone contusions were significantly more prevalent in the skiing group than in the soccer group (96.2% vs. 89.1%, $p < 0.001$). In terms of location, skiing injuries predominantly presented with unicondylar lesions of the LFC (58.7%), whereas soccer injuries more frequently involved bicondylar lesions (65.5%). The BCR at the LFC was significantly greater in the skiing group (0.26 ± 0.08) compared to the soccer group (0.21 ± 0.06 , $p < 0.001$). Although the overall incidence of meniscal injury was higher in soccer (63.5%) than in skiing (45.0%), the patterns differed distinctly. Skiing injuries primarily involved the lateral meniscus (75.8%), whereas soccer injuries more often involved the medial meniscus (23.5%) or both menisci (30.4%). Medial collateral ligament (MCL) injury was notably more frequent in the skiing group (35.1%) compared to the soccer group (8.3%, $p < 0.001$).

DISCUSSION. The distinct injury patterns observed suggest that while the fundamental limb positions during ACL rupture remain largely consistent across both sports, variations in stance and sport-specific loading conditions lead to different clinical presentations. The combination of frequent MCL injuries, severe unicondylar LFC bone contusions, and predominant lateral meniscus involvement in skiers points to a mechanism involving pronounced valgus loading combined with internal rotation. This specific loading pattern likely results in a transient dislocation of the lateral compartment, causing high-energy impact damage to the LFC and lateral meniscus.

CONCLUSIONS. Skiing-related ACL injuries are characterized by more frequent and severe bone contusions of the lateral femoral condyle, predominant lateral meniscus tears, and a higher incidence of MCL injuries compared to soccer. These findings highlight a unique, high-energy injury mechanism in skiing affecting the lateral knee compartment. Understanding these sport-specific patterns is crucial for improving diagnostic accuracy and developing targeted preventive strategies for skiers.

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A New Mechanism of ACL Injury in Skiing - New Phantom Foot Mechanism -

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Keywords: Anterior cruciate ligament injury, alpine skiing, phantom foot mechanism, video analysis, biomechanics, injury mechanism

INTRODUCTION. The exact mechanism of anterior cruciate ligament (ACL) injuries remains unclear. Previous studies have shown differences in associated injury patterns between skiing and ground-based sports, suggesting sport-specific mechanisms. Several mechanisms have been proposed for ACL injuries in skiing, including the phantom foot mechanism, slip-catch mechanism, and boot-induced mechanism, but no consensus has been reached. This study aims to present a new mechanism of ACL injury by analyzing five video-documented cases with confirmed diagnoses, demonstrating a previously unreported injury pattern.

METHODS. Three experts—two knee surgeons and one biomechanics specialist—visually analyzed four videos of confirmed ACL injuries. From each video, six sequential still frames starting from a predefined moment and the suspected moment of injury were extracted. Joint positioning, movement patterns, and biomechanical factors were assessed.

RESULTS. All injuries occurred during high-speed skiing. Three cases happened during turning maneuvers, and one occurred upon landing. In every case, the injury was involved with the downhill ski side. At the moment of injury, skiers maintained a wide stance (about 2 times shoulder width), with the knee joint was in valgus and flexed to approximately 60–80 degrees. The tibia appeared internally rotated, and in all cases, the skier rolled forward immediately after the injury.



Figure 1.

DISCUSSION. Skiing has been associated with distinct injury patterns compared with ground-based sports, including a higher incidence and severity of lateral meniscal injuries, bone bruises, and medial collateral ligament injuries. The injury mechanism proposed in this study may account for these differences.

CONCLUSIONS. The four cases analyzed in this study exhibit biomechanical characteristics distinct from previously described ACL injury mechanisms in skiing. This newly observed mechanism may be considered a modified form of the classic phantom foot mechanism. These findings could contribute to the development of future ACL injury prevention strategies in alpine skiing.

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The Role of Hand Dominance in Traumatic Shoulder Injuries during Winter Sports : A Comparative Analysis of Fractures, Dislocations, and Rotator Cuff Tears

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Keywords: shoulder, dominant hand, shoulder dislocation, shoulder trauma, rotator cuff tear, winter sports

INTRODUCTION.

Upper extremity injuries, particularly those involving the shoulder, are common in winter sports due to falls and high-energy trauma. While hand dominance is known to influence upper limb biomechanics and functional use, its role in traumatic shoulder injuries during winter sports has not been well characterized. Understanding whether the dominant arm is preferentially involved may provide insight into injury mechanisms and inform prevention strategies.

METHODS.

We conducted a retrospective epidemiologic analysis of patients who sustained traumatic shoulder injuries related to winter sports activities at a tertiary referral center. Injuries were classified into three categories: fractures, shoulder dislocations, and rotator cuff tears confirmed by imaging studies. Hand dominance was determined through medical records and patient interviews. The side of injury was categorized as dominant or non-dominant, and injury patterns were compared between groups. Subgroup analyses were performed according to injury type.

RESULTS.

A total of 355 patients with winter sports-related traumatic shoulder injuries were identified. Of these, 245 patients sustained fractures involving the clavicle or proximal humerus, and 110 patients sustained non-fracture injuries, including shoulder dislocation, rotator cuff tear, and SLAP lesions. Hand dominance could not be determined in 74 fracture cases and 42 non-fracture cases. Consequently, 171 fracture patients and 68 non-fracture patients were included in the final analysis.

Among fracture injuries, 62 patients (36.3%) sustained injuries to the dominant arm, while 109 patients (63.7%) sustained injuries to the non-dominant arm. In contrast, among patients with shoulder dislocation or soft-tissue injuries, 46 patients (67.6%) sustained injuries to the dominant arm, compared with 22 patients (32.4%) involving the non-dominant arm.

The distribution of injury laterality differed significantly between fracture and non-fracture injury groups ($\chi^2 = 18.11$, $p < 0.001$), indicating a strong association between hand dominance and injury type.

DISCUSSION.

This study demonstrates a clear association between hand dominance and injury type in winter sports-related traumatic shoulder injuries. Fracture injuries predominantly involved the non-dominant arm, whereas shoulder dislocations and soft-tissue injuries, including rotator cuff tears and SLAP lesions, were significantly more common in the dominant arm. This contrasting laterality pattern suggests that different injury mechanisms underlie fracture and non-fracture shoulder injuries in winter sports.

A plausible explanation for the predominance of dominant-arm involvement in dislocations and soft-tissue injuries is the instinctive protective response during falls. Individuals are more likely to extend or brace themselves using their dominant arm, which may increase tensile and rotational forces across the shoulder joint, predisposing it to instability and soft-tissue injury. In contrast, fractures of the clavicle or proximal humerus may more commonly result from direct impact or collision mechanisms, in which limb dominance plays a lesser role or the non-dominant side is exposed during loss of balance.

These findings support the concept that the dominant arm functions as a protective limb during falls, potentially reducing catastrophic injury but increasing susceptibility to specific shoulder pathologies. From a prevention perspective, recognition of dominance-related injury patterns may inform targeted fall-prevention education,

particularly strategies aimed at reducing arm-first impact during falls, as well as the development of protective equipment designed to mitigate dominant-arm loading in winter sports.

CONCLUSIONS.

Hand dominance influences injury patterns in winter sports-related shoulder trauma and should be considered in prevention strategies.

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Title: Clinical Characteristics and Treatment Outcomes of Proximal Humerus Fractures in Winter Sports: Comparison between Skiing and Snowboarding Injuries

Background: Skiing and snowboarding are popular winter sports, but they frequently result in proximal humerus fractures due to falls. This study aimed to compare injury characteristics and treatment methods between skiing and snowboarding groups and to analyze their clinical outcomes.

Methods: We retrospectively analyzed 59 patients who visited our center for shoulder injuries sustained during winter sports, specifically identifying 38 skiers and 17 snowboarders. We reviewed demographic data, injury mechanisms, fracture classifications, treatment modalities (surgical vs. conservative), and range of motion (ROM) at the final follow-up. Statistical analyses were performed using the t-test and Chi-square test, with a p-value < 0.05 considered statistically significant.

Results: There were no statistically significant differences in mean age ($p=0.207$) or gender distribution ($p=0.596$) between the two groups. 'Slip down' was the most common injury mechanism in both groups. However, a significant difference was observed in treatment modalities. The snowboarding group had a significantly higher rate of surgical treatment (82.4%) compared to the skiing group (50.0%) ($p=0.032$). Regarding clinical outcomes at the final follow-up, the conservative treatment group showed significantly better Forward Flexion (mean 171.5°) compared to the surgical group (mean 158.3°) ($p=0.014$). This likely reflects the greater severity and complexity of fractures in the surgical group.

Conclusion: Snowboard-related proximal humerus fractures required surgical intervention significantly more often than ski-related fractures. While overall treatment outcomes were favorable, patients requiring surgery for severe fractures demonstrated relatively limited range of motion compared to the conservative group, suggesting the need for aggressive rehabilitation.

Keywords: Winter sports, Proximal humerus fracture, Skiing, Snowboarding, Surgical treatment

Medial-to-Lateral Hamstring Muscle Balance and Frontal-Plane Knee Loading: Implications for ACL Injury Prevention in Female Skiers and Snowboarders

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Keywords: ACL Injury, Hamstring Morphology, Sex Differences, Knee Valgus, Snowsports, Injury Prevention

INTRODUCTION. Anterior cruciate ligament (ACL) injuries are highly prevalent in snowsports, particularly during high-energy landings and carving maneuvers that induce significant frontal-plane loading (Davey et al., 2019). The knee valgus moment (KVM) is a critical biomechanical risk factor for these injuries (Hewett et al., 2005). While the hamstring-to-quadriceps (H:Q) ratio is commonly studied, the specific contribution of medial-lateral hamstring balance to knee stability in snowsports-related movements remains unclear. This study investigated the association between the medial-to-lateral hamstring (HM:HL) thickness ratio and peak KVM across different functional tasks, focusing on sex-specific differences relevant to the high ACL injury rates observed in female athletes.

METHODS. Thirty-one healthy adults (17 males, 14 females) participated. Ultrasound imaging measured the thickness of the semitendinosus (ST), biceps femoris (BF), vastus medialis (VM), and vastus lateralis (VL). Kinematic and ground reaction force data were collected during walking (control), single-legged landing, and sidestep cutting—tasks representing the dynamic demands of skiing and snowboarding. The HM:HL thickness ratio and peak KVM (normalized to BW*height) were calculated. Pearson's correlation coefficients were used to assess the relationship between muscle morphology and kinetics.

RESULTS. In the pooled group, no significant correlation was found between the HM:HL ratio and peak KVM. However, in females only, a significant negative correlation was consistently observed across all tasks: walking ($r = -0.58, p < 0.05$), single-legged landing ($r = -0.56, p < 0.05$), and cutting ($r = -0.57, p < 0.05$). This indicates that a relatively smaller medial hamstring thickness is associated with higher knee valgus loading in females. No such correlations were identified in males.

Table 1. Pearson correlation coefficients (r) and p value (p) between the HM:HL thickness ratio and peak knee valgus moment across functional tasks by sex.

Task	Female (r)	Female(p)	Male (r)	Male(p)
Walking	-0.58	0.03*	-0.12	0.65
Single-legged Landing	-0.56	0.04*	-0.08	0.74
Sidestep Cutting	-0.57	0.03*	-0.15	0.58

DISCUSSION. The findings suggest that medial-lateral hamstring imbalance is a sex-specific morphological factor influencing knee stability. For female skiers and snowboarders, who often exhibit greater dynamic valgus during landings, a robust medial hamstring may be vital to resist valgus moments (Toor et al., 2019). Unlike traditional H:Q ratios, the HM:HL ratio specifically addresses the frontal-plane stabilizers. In snowsports, where external forces are unpredictable, this imbalance may exacerbate the risk of ACL rupture during recovery from "out-of-balance" positions.

CONCLUSIONS. Relatively smaller medial hamstring thickness increases frontal-plane knee loading in females, potentially increasing susceptibility to ACL injuries during skiing and snowboarding maneuvers. Targeted conditioning programs for female snowsports athletes should emphasize medial hamstring development to optimize knee joint stability and reduce injury risk.

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Age-specific Patterns of Concomitant Bone Contusions and Meniscal Tears in Skiing-Related Anterior Cruciate Ligament Injuries

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Keywords: Anterior cruciate ligament, skiing injury, bone contusion, meniscal tear, age

INTRODUCTION. Whether age-related biomechanical factors influence the pattern of concomitant injuries during skiing-related anterior cruciate ligament (ACL) rupture remains poorly understood. This study aimed to investigate the age-specific distribution of bone contusions and meniscal injuries among recreational adolescents, younger adults, and older adults.

METHODS. This multicenter retrospective cohort study, approved by the institutional review board, analyzed MRI data from skiers within 6 weeks of ACL injury. Patients were grouped as adolescents (≤ 19 years, $n = 54$), younger adults (20–49 years, $n = 339$), or older adults (≥ 50 years, $n = 43$). Meniscal tears types and femoral and tibial bone contusions locations were compared using chi-square tests and adjusted standardized residuals (ASR). P value < 0.05 and $ASR > 1.96$ were considered statistically significant.

RESULTS. The incidence of medial meniscus (MM) tears increased significantly with age (adolescents, 3.7%; younger adults, 15.0%; older adults, 34.9%; $p < 0.001$), whereas tear type did not differ among groups ($p = 0.591$). In terms of distribution ($p < 0.001$), adolescents were primarily associated with isolated lateral meniscus (LM) tears (ASR, 2.04), whereas older adults showed a higher prevalence of both isolated MM (ASR, 2.35) and combined MM+LM tears (ASR, 2.28). Femoral bone contusion patterns differed by age ($p = 0.022$), with adolescents showing isolated lateral femoral condyle (LFC) involvement (ASR, 2.09) and older adults exhibiting a trend toward isolated medial femoral condyle (MFC) contusions (ASR, 1.96). Regarding tibial contusion ($p = 0.018$), adolescents were significantly associated with combined lateral (LTP) and medial tibial plateau (MTP) contusions (ASR, 2.99), whereas older adults were characterized by isolated LTP involvement (ASR, 2.00).

DISCUSSION. Increased MM tears and MFC contusions in older adults suggest acute-on-chronic failure in degenerative, non-elastic MM environments or medial compartment overload in varus alignment. Regarding tibial bone contusion, adolescents' bi-compartmental tibial contusion reflects inherent joint laxity allowing greater tibial subluxation and subsequent impact during reduction. Conversely, isolated LTP involvement in older adults likely results from increased joint stiffness and lower-energy injury thresholds, which limit the impact zone.

CONCLUSIONS. Concomitant injury patterns following ACL tears were influenced by age-specific biomechanics and joint environments. While adolescents exhibited lateral-dominant injury with bi-compartmental tibial contusion (isolated LM, LFC, and combined LTP+MTP), older adults showed a predisposition toward medial-sided injury with localized lateral tibial contusion (MM, MFC, and isolated LTP). These findings suggest that age-tailored approaches could aid in developing more effective diagnostic and preventive strategies.

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Elite vs. Non-elite Skiers: Distinct Meniscal and Osseous Injury Patterns in ACL Rupture

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Keywords: Anterior cruciate ligament, skiing injury, bone contusion, meniscal tear, elite skiers, propensity score matching

INTRODUCTION. The influence of athletic expertise on concomitant injury patterns following skiing-related anterior cruciate ligament (ACL) rupture remains unclear. While elite skiers are exposed to higher-energy mechanisms, recreational skiers may sustain injuries under less controlled biomechanical environments. This study aimed to compare meniscal and osseous injury patterns between elite and non-elite skiers.

METHODS. This multicenter retrospective study, approved by the institutional review board, analysed MRI scans obtained within 3 months of ACL rupture. Patients were classified as elite (n = 40) or non-elite (n = 361) skiers. Propensity score matching based on age and body mass index (BMI) was performed at a 1:3 ratio. Injury patterns including medial collateral ligament injury (MCL) grade, medial meniscus (MM) tear, lateral meniscus (LM) tear, femoral and tibial bone contusions were compared using chi-square or Fisher's exact tests followed by adjusted standardized residuals (ASR). *P* value < 0.05 and ASR > 1.96 were considered statistically significant.

RESULTS. A total of 39 elite skiers were matched with 117 non-elite skiers, achieving balance in age (24.95 vs 24.71 years, standardized mean difference (SMD) = 0.029) and BMI (23.76 vs 23.57 kg/m², SMD = 0.055). Elite skiers showed a significantly higher prevalence of grade II MCL injury (28.2% vs 12.0%, ASR = 2.39), with lower rate of grade III MCL injury without significance (5.1% vs 15.4%, ASR = 1.66). The overall prevalence of meniscal tears was higher in elite skiers (no tear: 38.5% vs 70.1%, *p* = 0.001), driven primarily by a markedly increased rate of isolated LM tears (51.3% vs 18.8%). Elite skiers exhibited a much higher incidence of femoral contusions (*p* = 0.005), particularly isolated LFC (76.9% vs. 45.2%, ASR = 3.43). Tibial contusions were also more frequent in elite skiers (*p* = 0.004), characterized by a higher rate of combined lateral and medial tibial plateau contusions (35.9% vs 11.4%, ASR = 3.46).

DISCUSSION. The higher prevalence of isolated LM tears, isolated LFC contusion, and bi-compartmental tibial contusions in elite skiers suggests a higher-energy injury mechanism. This likely reflects the high velocity pivoting and extreme loading conditions in competitive skiing, which lead to greater tibial subluxation with rotation and subsequent impact during reduction.

CONCLUSIONS. Elite skiers were found to exhibit significantly different concomitant injury patterns in ACL rupture compared with non-elite skiers, particularly with respect to LM tears, LFC contusion, and bi-compartmental tibial contusions. These findings highlight the importance of considering athletic level when interpreting MRI findings and tailoring injury prevention strategies in skiing populations.

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Different Patterns of Humeral Shaft Fractures in Skiers versus Snowboarders: The Influence of the Ski Pole on Injury Mechanism

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Introduction: Humeral shaft fractures in alpine sports are often high-energy injuries associated with significant morbidity. While the injury mechanisms in skiing and snowboarding differ due to equipment, specifically the use of ski poles, comparative studies on fracture patterns are limited.

Purpose: This study aims to compare the fracture patterns of the humeral shaft between skiers and snowboarders and to evaluate the biomechanical role of the ski pole in torsional injuries.

Methods: We retrospectively reviewed 16 patients (7 skiers, 9 snowboarders) from multiple centers who presented with humeral shaft fractures. Demographics, mechanism of injury (e.g., slip down, direct blow), and fracture morphology were analyzed. Fracture patterns were categorized according to the AO/OTA classification.

Results: The fracture patterns differed significantly between the two groups. In the snowboarder group (n=9), the dominant pattern was the wedge fracture (AO/OTA Type B2), observed in 66.7% (6/9) of cases, suggesting a mechanism of direct bending force upon impact. Conversely, the skier group (n=7) predominantly exhibited simple spiral or oblique fractures (AO/OTA Type A, 6/7 cases). Specifically, Type A1 (simple spiral) fractures were found exclusively in skiers (3/7) or snowboarders with atypical mechanisms. Notably, the only skier who sustained a Type B2 wedge fracture (Case 16) had a distinct mechanism of "direct blow," unlike the "slip down" mechanism observed in other skiers.

Conclusion: Skiers and snowboarders exhibit distinct humeral shaft fracture patterns. Snowboarders are prone to wedge fractures (Type B) resulting from direct impact or bending forces. In contrast, skiers are more susceptible to simple spiral fractures (Type A), likely caused by indirect torsional forces generated when the ski pole acts as a lever arm during a fall. These findings suggest that pole entrapment is a critical risk factor for torsional fractures, highlighting the importance of educating skiers to release poles during falls to prevent spiral humeral injuries.

Title: Intelligent Orthopedics: The Next Wave of Musculoskeletal AI

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Abstract:

The global burden of musculoskeletal disorders continues to escalate with aging populations and increased activity demands, presenting persistent clinical and economic challenges. In response, *Intelligent Orthopedics*—the integration of advanced artificial intelligence (AI) within musculoskeletal healthcare—has emerged as a transformative paradigm. This presentation synthesizes the author's body of work on AI-driven diagnostic and prognostic systems, spanning deep learning-based imaging analysis, prediction of clinical outcomes, and decision support models that bridge radiological data with actionable clinical insight.

Central to this discourse is the development and validation of AI algorithms tailored for musculoskeletal imaging modalities, including radiographs, magnetic resonance imaging (MRI), and computed tomography (CT). These models have achieved high diagnostic accuracy across conditions such as osteoarthritis severity grading, ligamentous injury detection, and spinal pathology classification, demonstrating robustness through multicenter datasets and external validation cohorts. Beyond image classification, our research advances include predictive models for surgical outcomes and recovery trajectories, leveraging multimodal features to inform personalized care pathways.

We highlight methodological innovations that enhance model explainability and clinical trust, such as attention-based visualizations and integration of domain-specific priors. In addition, frameworks for real-world deployment are discussed, encompassing clinical workflow integration, regulatory considerations, and interoperability with existing health information systems. Emphasis is placed on rigorous evaluation metrics—sensitivity, specificity, AUROC—and prospective validation to ensure clinical relevance.

This work underscores that the next wave of musculoskeletal AI is not merely technical sophistication but clinically oriented intelligence that augments clinician decision-making, optimizes resource utilization, and ultimately improves patient outcomes. The presentation concludes with strategic directions for future research, including federated learning for collaborative AI development, longitudinal outcome prediction, and embedding AI as a core component of precision orthopedics.

Keywords: musculoskeletal AI, intelligent orthopedics, deep learning, medical imaging, clinical decision support, predictive modeling, explainable AI

Comparative Analysis of “Around-Elbow” Injury Patterns and Clinical Management in Young Recreational Snowboarders and Skiers

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INTRODUCTION. Winter sports injuries among recreational users represent a significant portion of seasonal orthopedic visits, requiring a detailed understanding of sport-specific injury patterns for optimal clinical outcomes. This study aims to analyze the differences in around-elbow injury patterns and subsequent clinical management between young recreational snowboarders and skiers, with a particular focus on injury mechanisms, specific fracture types, and the distinct absence of concurrent lower limb trauma.

METHODS. A retrospective review was conducted on 37 recreational patients, comprising 22 males and 15 females. The study cohort was notably young, with a high concentration of patients in their 20s and 30s, ranging from 8 to 59 years. Patients were categorized into a Snowboarding group (n=23, 62%) and a Skiing group (n=14, 38%), all of whom were identified as recreational participants such as office workers or students. Data analysis included specific injury mechanisms, fracture classifications such as AO/OTA, Mason, and O’Driscoll types, and the chosen intervention methods ranging from conservative management to surgical fixation.

RESULTS. All recorded injuries occurred during recreational activity, and notably, no associated lower limb injuries involving the hip, knee, or ankle were reported within this cohort. Snowboarders predominantly suffered from "slip down" accidents (n=19) while landing on an outstretched hand, which led to a high frequency of elbow instability, including posterior dislocations, O’Driscoll type coronoid fractures, and Monteggia fractures. Surgical intervention was frequently required for snowboarders, involving Open Reduction and Internal Fixation (ORIF) with plates or screws for Monteggia fractures and Regan-Morrey type II injuries, as well as ligamentous stabilization for LCL and MCL ruptures. In contrast, skiers exhibited a wider variety of mechanisms, including higher-energy "rolling down" or collision events. Common injuries among skiers included radial head fractures of Mason type II/III and distal humerus fractures in the AO/OTA 13 series. Treatment for skiers varied from ORIF with plates for complex articular fractures to conservative management, such as casting or bracing, for stable O’Driscoll Tip 1 fractures. While associated upper body trauma included clavicle and ulnar shaft fractures, neurological involvement, such as ulnar nerve symptoms, was limited to approximately 5% of the total cases.

CONCLUSIONS. In young recreational participants, winter sport injuries are characterized by isolated, high-impact around elbow trauma without concurrent lower limb involvement. Snowboarders are significantly more prone to instability-related injuries and Monteggia-type fractures that often necessitate complex surgical fixation. Conversely, skiers more frequently sustain intra-articular fractures of the distal humerus and radial head. These findings suggest that for the young recreational demographic, injury prevention should focus heavily on upper limb protection, and surgical strategies should be tailored to the sport-specific injury patterns of the around elbow

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