10th INTERNATIONAL CONGRESS ON SCIENCE AND SKIING

January 28 - February 1, 2025
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Book of abstracts

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Preface

This book collects the abstracts of the presentations from the 10th International Congress on Science and Skiing (ICSS 2025), held in Val di Fiemme, Italy, from January 28 to February 2, 2025.

The scientific program includes: 1 honorary speech by Professor Erich Müller; 4 keynote speeches presented by Professors Kirsty Elliot-Sale (UK), Øyvind Sandbakk (NOR), Marco Narici (ITA), and Jörg Spörri (SWI). Additionally, the program hosts more than 100 presentations: 7 invited speeches; 15 oral sessions covering various topics; and a poster session featuring 3-minute podium presentations.

To maintain the high scientific standard, a peer review process was utilized to select the abstracts submitted. The abstracts were reviewed by the commission regarding content, topic, and structure according to the guidelines of the ICSS, and when the commission had comments and recommendations for revision, these were sent to the authors.

Submissions were received from 14 different countries, with Italy, Germany, Japan, Sweden, and the USA being the most represented. The presentations included in the congress cover a wide range of topics across different skiing disciplines, with Alpine Skiing, Cross-Country Skiing, Ski Mountaineering, and Biathlon being the disciplines that are most frequently the subject of the studies reported.

The congress offers a unique opportunity for paretcipants to meet and discuss the science of skiing and to build and develop synergies and collaborations. The abstracts collected here testify to the scientific content.

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CANADIAN FEMALE PERFORMANCE IN ALPINE SKI RACING: UNDERSTANDING REPRESENTATION SUCCESS ACROSS LEVELS.

Patricia K. Doyle-Baker[1,2]

[1]Human Performance Lab, Faculty of Kinesiology, University of Calgary, Alberta Canada
[2]Alberta Children's Hospital Research Institute, University of Calgary, Calgary, AB, Canada

Keywords: Alpine ski racing, Canada, conversations, females, and semi structured interviews

INTRODUCTION: Traditional forms of governance structure for organization groups typically exist with a Board of Directors and a CEO [1]. There are, however, less formal models particularly in sport that can be effective to meet current needs. Influential aspects of these models include funding, volunteer reliance, and competition barriers associated with geographical distances. These factors exist within Alpine Canada Alpin (ACA), the parent organization of the provincial ski organizations (PSOs). The PSOs rely on specific working groups and a grassroots leadership model [2] to anticipate and adapt to the requirements of their membership. The inclusivity of female representation is one such need. Therefore, the presentation goal was to share the perspectives on the success of female performance (levels: athlete, coach, and race officials) in alpine ski racing based on those working fulltime in the Canadian system of alpine ski racing.

METHODS: Using convenience sampling, six individuals (age range 25-58 yrs) with ACA affiliation and registered with a PSOs (BC, Alberta, Ontario) were invited to reply by email to a four broad topics related to females (top down perspective, COVID training effect, performance variables, and coaching). Detailed responses were collected from 4 (50% F) individuals and 3 participated in a semi-structured-conversational interview. The qualitative method of phenomenography[3] was chosen to help with understanding the perspectives on Canadian alpine female ski racing success.

RESULTS: Eight themes based on increasing female representation in alpine ski racing emerged: all levels -1. devoting time to conversations, 2. building relationships; athlete -3. self-directed school, 4. youth age bias, 5. social media; coach and officials -6. developing expertise and providing support, 7. leading by example and 8. expert use of situational influence [4].

DISCUSSION/CONCLUSIONS: Inspiring others to adopt changes can be influenced by the grassroots level and lead by the power of experience when limited resistance is met from the head organization(s) [5]. In simple language "success is occurring through the long game in Canada" as PSOs in cultivate from within a collective drive to achieve inclusiveness with a more balanced female representation in athletes, coaches, and officials.

REFERENCES:

[1] Mercier R. (2023, Aug.16). https://sirc.ca/articles/superstars-or-a-super-team-building-capacity-to-play-like-a-championship-team/
[2] Mercader l. (2016, Feb.) https://www.volunteertoronto.ca/blogpost/1296563/239172/From-The-Bottom-Up-Grassroots-Leadership-Models
[3] Åkerlind GS. (2012). *High Educ Res Dev*., 31:115–27.
[4] Pearce CL, & Manz CC. (2005, April). *Organizational Dynamics* 34(2): 130–140.
[5] Matthews T. (2025, Jan. 8). https://sirc.ca/articles/superstars-or-a-super-team-building-capacity-to-play-like-a-championship-team/

DIFFERENT APPROACHES TO ANALYZE START STRATEGIES OF WORLD CUP RACERS IN ALPINE SKI RACING

*Peter Spitzenpfeil *1*, *Chris Hummel 1*, Maren Goll *1*, *Andreas Huber* [2], *Karlheinz Waibel* [3]

[1]Applied Sport Science, Technical University of Munich, Munich, Germany, [2]Olympiastützpunkt München, Munich, Germany, [3]German National Ski Team, Munich, Germany

Keywords: alpine Skiing, start strategies, qualitative analysis

INTRODUCTION: Alpine skiing speed races are often decided by fractions of a second. Therefore, even the start sequence especially in flat terrain, has the potential to influence on the total performance [1]. By analyzing the start's critical elements, several studies emphasize that even small improvements in technique or mental preparation can make a significant difference in overall race outcomes. Main focus of those studies has been put on the initial acceleration out of the start gate and the concerning role of explosive leg strength, reaction times, and efficient use of the start gate [2].

In the current study focused on the phase after leaving the gate and analyzed the different skiing-techniques of World-Cup athletes to accelerate into the course of a World-Cup Super-G race.

METHODS: The start performance of 30 elite racers has been analyzed at the FIS Ski World-Cup Super-G in Garmisch-Partenkirchen in 2024. The start area was recorded by 7 video-cameras (60Hz) from different perspectives and angles. Several time markers had been defined to extract the absolute performance: opening start gate – passing gate 1 (time to gate 1) – passing gate 2 (time gate1 to gate 2) – int. time 1 – total race time.

To analyze the start strategies, the sub-techniques of cross country skiing (skating) following the convention in Nilsson et al. [3] have been used to classify the different movements. Cross-country experts have rated the movement quality.

RESULTS/DISCUSSION: First results show high correlation (.89**) between "time to gate 1" and "int. time 1" but not to total race time. The different sub-techniques have been used very individual and variable. Number of leg movements differed from 4-7, supported by different numbers of poling actions. No certain start strategies concerning nations or teams have been detected. Results on movement quality will be presented at the congress.

CONCLUSION: Due to the importance of the start performance especially at start in flat terrain, the used technique and the movement quality of this techniques might be crucial for the total race performance.

REFERENCES:

[1] Supej, M. et al, 2018 Journal of Sports Sciences, 37:6, 647-655
[2] LeMaster, R., 2010 Journal of Sports Science and Medicine, 9, 131-137
[3] Nilsson, J. 2004 Sports biomechanics, 3(1), 85–107

ESTIMATING RACE TIME DIFFERENCES FROM TECHNICAL BOOSTING IN PARA NORDIC SIT-SKIING WITH SIMULATIONS

Julius Lidar[1], David Sundström [1]*

[1] Sports Tech Research Centre, Department of Engineering, Mathematics and Science Education, Mid Sweden University, Östersund, Sweden

Keywords: para nordic skiing, sit-skiing, cross-country skiing, para sports

INTRODUCTION: To enable fair competitions, para nordic sit-skiing (PNSS) athletes are grouped based on their impairments effect on performance ability, i.e. classification. Each class is assigned a time factor which is multiplied with race times to get comparable corrected times. Time factors do not consider system mass (body and equipment) although it can differ significantly. Force generation within PNSS classes have been quantified [1] and course sections crucial to PNSS race times have been identified [2], but there is limited research on system mass in PNSS. Therefore, the aim was to quantify the effect of system mass on race times in PNSS classes.

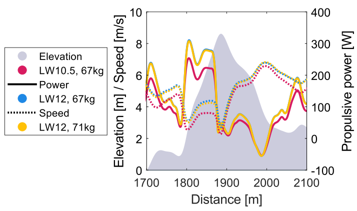
METHODS: System masses and GPS-data were collected from 11 PNSS athletes (4 classes) during the 10-km world championship race in Östersund, 2023. More than 50 mathematical models adhering to Newton's 2nd law of motion were formulated, which included propulsive power (PP) and forces from gravity, friction and air drag. Model parameters were individually optimized to minimize the error between measured and modeled time along the entire race. In the final model, 2 PP parameters were used to differentiate between the classes. The average corrected race time from the top half of the official results list was multiplied with 22/23 season time factors to obtain typical race times for each class. A model for a typical skier (TS) of each class was then created from the typical race times and linear regressions between race times and the 2 PP parameters, respectively. All other parameter values were identical for all classes.

The model for each TS was used to obtain PP profiles for the entire race which was then used to obtain race times for every TS with 3 different system masses (67, 69, and 71 kg). External force parameters were sampled from a normal distribution to reduce model sensitivity, totaling 4×3×500 simulations.

RESULTS/DISCUSSION: The table shows the mean race times for the TSs with a system mass of 69 kg and the difference in mean race time with 2 kg system mass increase and reduction, respectively. On average, the race times differ 0.48% per kg from the 69 kg race times, but more data in each class is needed to further investigate possible differences between classes.

Class	ΔT, -2 kg [s]	T, 69 kg [min:s]	ΔT, +2 kg [s]
LW10.5	-22.8	34:42	21.8
LW11	-18.5	32:33	18.8
LW11.5	-17.1	31:43	17.7
LW12	-15.5	30:47	16.4

The figure shows larger differences in speed between classes with the same system mass than within a class with different system masses, but similar overall distributions (for a course section).



CONCLUSION: The differences in race time due to altered system mass could be used as guidance if equipment restrictions are considered to minimize the influence from equipment on competition results. It can also be used by athletes and teams in prioritizing their competition preparations.

REFERENCES:

[1] Karczewska-Lindinger, M. et al, 2021 J. Sci. Sport Exerc.
[2] Rispal, G. et al, 2023 J. Sports Sci.

The Female Skier – Current Insights and Future Directions

Guro Strøm Solli[1]

[1]Department of Sport Science and Physical Education, Nord University, Bodø, Norway

At the first Olympic Winter Games (OWG) in Chamonix in 1924, only 4% of the competitors were women. Female participation has steadily increased over the decades, rising to 20% at Squaw Valley in 1960, 30% at Lillehammer in 1994, 40% at the 2010 Vancouver Olympics, and is expected to reach 47% at the Milano Cortina 2026 OWG.[1] Nordic skiing, a core component of cross-country skiing (XCS), biathlon (BIA), and Nordic combined (NC), will feature in 22% of the 116 total events and 60% of the 43 endurance events. Male XC skiers have competed in the OWG since its inception in 1924, but it wasn't until the 1952 Oslo Games that Lydia Wideman became the first female Olympic gold medalist in XCS. Biathlon saw its Olympic debut for men at the 1960 Squaw Valley Games, while women were first allowed to compete in 1992, with Anfisa Reztsova earning the first female Olympic gold in the discipline. Despite NC being part of the OWG for men since 1924, female NC athletes remain excluded and will not compete at the 2026 OWG.

A 2017 commentary[2] examined the evolution of training among champion XC skiers, highlighting that, prior to 1970, most top athletes in the sport were male lumberjacks. These men developed exceptional endurance and strength by running or skiing long distances to and from logging sites while working physically demanding, long hours in the woods. At the time, few women participated in XCS, and prevailing attitudes among coaches suggested that women could not handle the same training loads as men. However, the 1970s marked a turning point as women began training with similar loads as men, disproving misconceptions and driving advancements in their physiology, training, and performance.

Although data on female skiers' training and physiology lagged behind that of their male counterparts for many years, research in this area has expanded significantly in recent decades. This invited lecture will provide current insights into the long-term development of female skiers, focusing on: 1) key characteristics of the long-term development of successful athletes; 2) unique aspects of the female-specific development process, including training and performance during adolescence, the impact of the menstrual cycle, the use of hormonal contraceptives, and training during pregnancy and postpartum; and 3) sex differences in performance, physiology, and training. Finally, future directions to further support the development of female skiers will be discussed.

References

1. IOC. Milano Cortina 2026 set to become the most gender-balanced Olympic Winter Games in history. IOC 2023 [Accessed 10.01.2025]; Availablefrom: https://olympics.com/ioc/news/milano-cortina-2026-set-to-become-the-most-gender-balanced-olympic-winter-games-in-history
2. Sandbakk Ø. The Evolution of Champion Cross-Country-Skier Training: From Lumberjacks to Professional Athletes. Int J Sports Physiol Perform. 2017 Feb;12(2):254-259. doi: 10.1123/ijspp.2016-0816. Epub 2017 Jan 17. PMID: 28095069.

ANALYSIS OF EXERCISE INTENSITY DISTRIBUTION AND SHOOTING PERFORMANCE IN A SUMMER BIATHLON SPRINT RACE

Martina Palumbo[1,2], *Lorenzo Bortolan*[1,3], *Roberto Modena*[1], *Gianluca Viscioni*[1,2], *Simone Bettega*[1,2], *Federico Schena* [1,2], *Chiara Zoppirolli* [1,3]

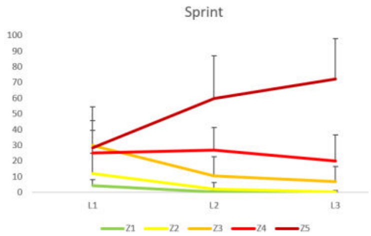
[1]CeRiSM (Research Center Sport Mountain and Health), University of Verona and Trento, Rovereto,Italy, [2]Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona,Italy, [3]Department of Engineering for Innovation Medicine, University of Verona, Verona, Italy,

Keywords: biathlon, heart rate, intensity distribution

INTRODUCTION: Biathlon is an Olympic endurance sport that combines cross-country skiing with precision rifle shooting. Biathlon performance has usually been analyzed in terms of skiing time, shooting accuracy, and time spent shooting, while limited investigation was conducted on the race physiological demands[1,2]. This study investigates exercise intensity distribution (EID) in different heart rate zones (Z1-Z5) across the laps of a summer biathlon sprint race, and whether EID affects the subsequent shooting performance.

METHODS: This study involved 17 high to world-level Italian biathletes (6 females and 11 males) competing in a national summer biathlon sprint race. Each athlete wore a heart rate monitor during the race. The individualized 5 heart rate intensity zones were established by analyzing each athlete's lactate curve, previously determined through a roller skies laboratory test. Shooting performance was evaluated as the number of targets hit during the race, shooting time and time to first shot. Thereafter, athletes were divided into 2 groups based on whether they spent less or more than 50% of the lap time in Z5 (group 1 and group 2 respectively). The Friedman test, followed by pairwise comparisons with Wilcoxon test was used to evaluate EID. Mann-Whitney U test compared EID for male and females and shooting performance between group 1 and group 2.

RESULTS/DISCUSSION: In the first lap of the race, the time spent in intensity zones Z3, Z4, and Z5 was similar (all $p > 0,05$). In the second lap, the time spent in Z5 began to increase accompanied by a decrease of time in Z3, leading to a distinct separation of the three zones in the third lap (all $p < 0.001$). Throughout the three laps, the percentage of time spent in Z4 remained relatively constant.
There were no gender differences in EID in all the laps. ($p > 0,05$)



Regarding shooting performance, there were no significant differences in shooting time and time to first shot for both the first and the second lap between group 1 and 2 ($p > 0,05$). The number of hit targets in prone shooting (after the first lap) did not differ between the two groups. Interestingly, in the standing shooting (after the second lap) a higher number of missed targets was found in the group that spend more than 50% of time in Z5 ($p < 0.05$).

CONCLUSION: The study showed that the percentage of race time spent in Z4 remained stable, with a decrease in Z3 coinciding with an increase in Z5 across laps. Additionally, variations in time spent in Z5 seems to influence the standing shooting performance. However, further research involving multiple competitions and a greater number of athletes is important to support these findings. For the first time we analized the effect of EID on shooting performance during a race; our results have important practical implications that coaches should take into account when planning physical and shooting training for biathletes or when working on pacing strategies.

REFERENCES:

[1]Laaksonen MS, et al, 2018 J Sport Health Sci.
[2] Luchsinger H, et al, 2019 Front Sports Act Living.

BIOLOGICAL MATURITY AND PERFORMANCE IN YOUTH ALPINE SKIING: AN ANALYSIS OF MOTOR SKILLS AND SPORT SPECIFIC SKILLS

Giulia Pelizzatti [1], Roberto Modena[1,2], Lorenzo Bortolan[1,3], Barbara Pellegrini[1,3], Chiara Zoppirolli[1,3]

[1]CeRiSM (Research Center Sport Mountain and Health), University of Verona and Trento, Rovereto, Italy, [2]Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona, Italy, [3]Department of Engineering for Innovation Medicine, University of Verona, Verona, Italy

Keywords: Biological maturity – Performance – Youth alpine skiing – Motor skills

INTRODUCTION: Alpine skiing is a complex sport that requires advanced agility, dexterity, and significant muscular engagement, primarily relying on anaerobic metabolism [1]. However, when considering young athletes, it is crucial to monitor and account for additional variables such us physical and biological growth, as well as gender differences, since boys and girls experience different rates of physical and performance development [2; 3]. The present study examined anthropometry, biological maturation, physical performance capacity and training habits in young alpine skiers, in relation to their actual alpine skiing performance capacity.

METHODS: A total of 79 male (M) and female (F) young skiers competing at provincial level and aged between 12 and 16 years (U14 and U16 categories), were analyzed. Anthropometric measurements were taken for each athlete; Mirwald Maturity Offset (MO) and age at Peak Height Velocity (PHV) were calculated. A battery of tests was proposed to evaluate lower-limb explosive and endurance strength, endurance, agility, core stability and flexibility. Additionally, the number of dry-land and on-snow training days were considered as training habits. Alpine skiing-specific performance (ASP) was evaluated by calculating an average percentage time-gap from winner in the best three races of the alpine-skiing circuit. The effect of biological maturity was analyzed by dividing the sample into three subcategories based on the Maturity Offset value (MO). Sex and age-category effects were verified with a *two-way ANOVA test,* and models predicting ASP index were derived for each group through a *forward multiple regression analysis*.

RESULTS/DISCUSSION: F showed advanced biological maturation and earlier PHV' age than M. Biological maturity status influenced motor performance only in male strength endurance capacity ($p < 0.05$), without influencing the ASP index ($p > 0.05$). M-U16 outperformed M-U14 in explosive strength and endurance capacity ($p < 0.05$), while F-U16 didn't show significant improvements in respect to F-U14. Gender differences were found in U14, where F showed better results in core stability and flexibility ($p < 0.05$). Conversely, in U16, M showed better explosive strength than F. ASP index variance was explained by explosive strength and ski-days in U14-M ($p < 0.001$), strength endurance and agility in U14-F ($p < 0.001$) and U16-M ($p < 0.001$), and by explosive strength and dry-land days in U16-F ($p = 0.012$). Chronological age influenced skiing capacity in U16-M, with older subjects showing a better ASP index ($p < 0.05$).

CONCLUSION: Moving from U14 to U16, males improve strength and endurance, while females tend to remain stable. Within age categories, biological maturity seems to influence strength endurance in males but has no impact on alpine skiing performance (ASP) in either gender. Conversely, chronological age, rather than biological age, seems to contribute to the model describing alpine skiing performance, along with motor abilities, dry-land and on-snow training days.

REFERENCES:

[1] Hydren, J. R. et al, 2013 Rewiew of Strength and Conditioning for Alpine Ski Racing
[2] Viru, A. et al, 1999 European Journal of Physical Education
[3] Lloyd, R. S. et al, 2014 Journal of Strength and Conditioning Research

PHYSICAL FITNESS FACTORS FOR ROLLER SKIING RACE PERFORMANCE

Shunya Uda[*1], *Naoto Miyamoto* [2], *Wako Kajiwara* [1], *Hiroshi Nakano* [1], *Keisuke Onodera* [1], *Ryoji Horimoto* [1], *Masaki Takeda* [1]

[1] Graduate School of Health and Sports Science, Doshisha University, Kyotanabe, Japan [2] NICHe, Tohoku University, Sendai, Japan.

Keywords: Cross-country skiing, Race performance, Physical fitness tests, GNSS analysis

INTRODUCTION: In cross-country skiing, higher levels of cardiorespiratory fitness and upper body power in athletes are associated with improved race performance [1]. Therefore, it is hypothesized that cardiorespiratory fitness and upper body power influence skiing characteristics during races, such as the frequency of sub-technique usage, skiing velocity, cycle length (CL), and cycle time (CT). The aim of this study is to elucidate the relationship between skiing characteristics during races and physiological factors measured in the laboratory, with the goal of identifying factors that contribute to enhanced race performance.

METHODS: A total of 16 male cross-country skiers (age: 19.8 ± 3.7 years) participated in this study, which involved a 10 km time trial on roller skis using the skating technique, as well as laboratory-based physiological tests. During the time trial, each skier was equipped with a GNSS device on their head to collect data on race time, and time-based usage ratios, skiing velocity, CL, and CT of sub-techniques (G2, G3, G4, G6, downhill). Sub-techniques were analyzed based on the head horizontal and up-down movement pattern measured by GNSS. The physiological tests included incremental exercise tests on a treadmill as pole walking (PW) and double poling (DP), where time to exhaustion (TTE), VO_2max, and VO_2max/kg were collected for the PW test, and TTE, VO_2peak, VO_2peak/kg were collected for the DP test. Additionally, the ratio of VO_2max in the PW test to VO_2peak in the DP test (VO_2%PW/DP) was calculated. Pearson's correlation coefficient was used to analyze variable relationships. Data normality was confirmed, and two-tailed tests with a significance level of 0.05 were conducted.

RESULTS: The average race time was 25:06 ± 2:02 min. The time-based usage ratios of each sub-technique were as follows: 1.4% for G2, 41.4% for G3, 29.0% for G4, 15.5% for G6, 11.1% for downhill. Race time was correlated with TTE, VO_2max in the PW test, and TTE, VO_2peak, VO_2peak/kg in the DP test ($r = -0.53$ to -0.76, $p < 0.01$ to 0.05). Skiing Velocity of G3, G4, G6 and downhill were correlated with TTE and VO_2max in the PW test, and TTE, VO_2peak, VO_2peak/kg in the DP test ($r = 0.55$ to 0.83, $p < 0.01$ to 0.05). CL of G3 was correlated with VO_2max in the PW test, and TTE, VO_2peak, VO_2peak/kg in the DP test ($r = 0.54$ to 0.70, $p < 0.01$ to 0.05). CL of G4 correlated with TTE and VO_2max in the PW test, and TTE, VO_2peak in the DP test ($r = 0.53$ to 0.64, $p < 0.01$ to 0.05). CL of G6 was correlated with VO_2max in the PW test, and TTE, VO_2peak in the DP test ($r = 0.56$ to 0.60, all $p < 0.05$). CT of G6 was correlated with TTE in both the PW and DP tests ($r = -0.62$ to -0.63, $p < 0.01$ to 0.05). Usage ratio of G3 was correlated with VO_2max in the PW test ($r = -0.54$, $p < 0.05$) and G4 was correlated with VO_2max in the PW test and VO_2peak in the DP test ($r = -0.53$ to -0.59, all $p < 0.05$).

DISCUSSION/CONCLUSION: These findings suggest that roller skiing performance is influenced not only by endurance capacity, as indicated by TTE and absolute VO_2max in the PW test, but also by DP performance. Notably, TTE in the DP test showed a strong correlation with race time ($r = 0.76$), suggesting that future efforts should focus on enhancing DP capacity.

REFERENCES:

[1]. Staib, J. L. et al, 2000 The Journal of Strength & Conditioning Research

OVARIAN HORMONES: FRIEND OR FOE OF FEMALE OLYMPIANS?

Kirsty Elliot-Sale

TRENDS, PERSPECTIVES, OPPORTUNITIES AND CHALLENGES WITH SENSOR TECHNOLOGY IN WINTERSPORTS

Thomas Stöggl[1,2], Cory Snyder[1,2], Michael Buchecker[1], Christoph Thorwartl[3]

[1]Department of Sport and Exercise Science, University Salzburg, Austria [2]Athlete Performance Center, Salzburg, Austria [3]Salzburg Research Forschungsgesellschaft m.b.H., Salzburg, Austria

Keywords: force interplay, IMU, motion quality, push-off model

Recent developments in sensor technology have made sensing units cheaper and easier to implement. These developments have made the application of "wearable technology", or smart sporting equipment appealing to a broad audience allowing measuring metrics of motion quantity (e.g. distance, time, number of cycles) and motion quality, or how well a sport technique is performed. In the current presentation the concept of an instrumented ski boot, an instrumented alpine ski using the PyzoFlex® sensor foil technology and the determination of force components and measures of effectiveness within various cross-country skiing (XCS) techniques applying a push-off model is presented.

The Atomic connected boot consists of an IMU mounted on the shaft of the boot. With this concept macroscopic metrics like turn detection, turn count (1) and jump detection (2) were developed while on a more microscopic level a skiing style detection algorithm and carving score concept (3) was established to determine the skiing/carving quality while skiing. Ski deflection is a performance-relevant factor in alpine skiing and the segmental and temporal curvature characteristics along the ski have lately received particular attention. Recently, a PyzoFlex® ski deflection measurement prototype was introduced that demonstrates high reliability and validity in both static and dynamic situations both in the laboratory (bending machine, bending robot, vibration measures) and in the field while skiing (4).

The primary mechanical determinant of XCS performance is the propulsive force from both skis and poles represented by the force components along the skiing direction. The determination of force components, the relative contributions of upper-and-lower-body work to propulsion and the translation of resultant forces into propulsive forces (effectiveness) is of interest from a general locomotor perspective but also for coaches and athletes to choose situation dependent the appropriate skiing technique, to develop more effective techniques and to tailor the general conditioning program according to the biomechanics of the single XCS techniques. In various studies resultant forces were recorded using pressure insoles, force bindings, force systems integrated into skis and poles. Force components were determined by track integrated force plates or combinations of resultant forces with 3D kinematic measures. Here we present a model to determine force components, effectiveness, upper vs. lower body contribution based on leg and pole forces and 3D kinematics in various XCS techniques.

In all presented concepts the challenge lies in further developments for integration into non-obtrusive technologies in communication with conventional measuring devices (e.g. smart watch, training app) allowing for enhanced quality of training/competition metrics, feedback systems assisting in technique training, support for ski equipment selection and equipment customization etc.

REFERENCES:

[1] Martínez, A et al. 2019 Front Sports Act Living
[2] Kranzinger, S et al, 2024 Plos One
[3] Snyder, C et al. 2021 Eur J Sport Sci
[4] Thorwartl, C et al, 2021-2023 Sensors

MULTI-CAMERA FRAMING OF DRY SLOPE SNOWBOARDING JUMPS

*Robbe Decorte [1 *], Robbe De Waele [1], Maarten Slembrouck [1], Steven Verstockt [1]*

[1] Ghent University – imec, IDLab, Sports Data Science, robbe.decorte@ugent.be

Keywords: storytelling, jump analysis, automatic video editing, sports data science

INTRODUCTION: While snowboarding was originally only performed in mountainous regions, the popularity of this sport combined with the unpredictability of natural snowfall has led to the creation of dry slopes, i.e., man-made artificial surfaces that simulate the feel of snow, allowing for year-round snowboarding practice and training. To enhance the experience at the dry slope, we've developed an automated video system that provides detailed jump analysis. Using three cameras, we capture athletes from multiple angles and generate zoomed-in videos for review. Our analysis reports, distilled from these videos, includes key metrics like airtime, takeoff speed, height, and distance.

METHODS: We automatically clip video segments by predicting the athlete's three-dimensional flight path. This prediction is used to project the athlete's estimated position onto the image plane, allowing us to frame the athlete effectively. To achieve this, we track the athlete's movement on the kicker using human pose estimation, which enables us to estimate his takeoff position and velocity.

Using the estimated takeoff parameters, we approximate the athlete's flight trajectory using projectile motion with air resistance. To streamline the analysis, we divide the jump into four stages: (1) the inrun, (2) takeoff, (3) airtime, and (4) landing stages, as illustrated in Figure 1.

RESULTS/DISCUSSION: Our framing method, which achieved zoom levels of 2x to 4x, provides a solid foundation for future research on snowboarding jump feedback. This includes applications requiring higher resolution footage, such as 3D human pose estimation and scene reconstruction. This could be achieved by utilizing the predicted trajectories to automatically steer a high resolution PTZ-camera (at which point timing and efficient computation becomes more important). Additionally, our analysis results complement subjective visual observations with objective metrics. However, further testing is needed to verify their accuracy.

CONCLUSION: This research provides a foundation for 3D human pose estimation of snowboarding jumps by using multi-camera video footage to estimate the athlete's flight trajectory. Future work can build upon this foundation by implementing automatic athlete tracking, enabling higher zoom levels and improved image resolution. Furthermore, a detailed jump analysis, including airtime, takeoff velocity, height, and distance, can be derived from the predicted trajectory. While this methodology was only demonstrated at a dry slope in Genk (Belgium), it can serve as a model/basis for similar research elsewhere.

REFERENCES:

[1] S. Matsumura, D. Mikami, N. Saijo, and M. Kashino, "Spatiotemporal motion synchronization for snowboard big air." [Online]. Available: http://arxiv.org/abs/2112.10909
[2] L. Jiang, B. Huo, Q. Sun, X. Chen, and X. Gao, "Intelligent training system for snowboard big air," in 2023 International Conference on Electrical, Computer and Communication Engineering (ECCE), pp. 1–4. [Online]. Available: https://ieeexplore.ieee.org/document/10101605

REPRODUCIBILITY OF CORTICAL SOMATOSENSORY EVOKED POTENTIALS IN CROSS-COUNTRY SKIING: A PROOF-OF-CONCEPT STUDY

Harri Piitulainen[1], Alessandra Giangrande[1,2], Alberto Botter[2], Giacinto Luigi Cerone[2], Magdalena Karczewska-Lindinger[3], Stefan Lindinger[3], Jarmo M Piirainen[1,4]

[1]University of Jyväskylä, Jyväskylä, Finland, [2]Polytechnic of Turin, Turin, Italy [3]Laboratory of Biomechanics of Skiing, Bormio, Italy, [4]Sport Technology Unit Vuokatti, Faculty of Sports and Health Science, University of Jyväskylä, Jyväskylä, Finland

Keywords: wireless EEG, motor control, balance performance

INTRODUCTION: Skiing has positive effects on human health and motor ability in daily life activities [1-2]. However, the brain basis of skiing induced balance and motor control benefits are unclear. To unravel these mechanisms, the high quality and reproducibility of the electroencephalographic (EEG) signals recorded during skiing are prerequisite for longitudinal skiing studies. We examined the reproducibility of the skiing evoked cortical EEG potentials during cross-country skiing.

METHODS: Four professional male skiers volunteered for two sessions 24-h apart (41 ± 3 y.o.) to perform 3-min of V2-skiing on a treadmill (Rodby, Sweden) at 2° elevation and at velocity matching 85% of their maximal heart rate. 32-channel EEG (ReC Bioengineering Laboratories and LISiN, Turin, Italy) somatosensory-evoked potentials (SEPs) were quantified to 15 supramaximal electrical stimulations at 150% of maximal M-wave to the right common tibial nerve delivered every three skiing cycles at 255 ms after onset of the gliding phase. The 200 µs stimuli amplitude was 43 ± 12 mA in 1st session and 37 ± 16 mA in 2nd session. In addition, ground reaction force and EMG from tibialis anterior, gastrocnemius medialis and soleus muscles were recorded.

RESULTS and DISCUSSION: Our newly developed light-weight wireless EEG showed high reproducibility in: (1) cortical location of peak SEP on Cz electrode above the leg area of the primary sensorimotor cortex, (2) peak SEP amplitude of 28 ± 5 µV in 1st session and 27 ± 6 µV in 2nd session and (3) peak SEP latency: N1 was 131 ± 16 ms and P2 was 227 ± 21 ms in 1st session, and N1 was 132 ± 9 ms and P2 was 237 ± 14 ms in 2nd session. In addition, we were able to record and synchronize multiple signals together by using a wireless synchronization unit [3].

CONCLUSION: Our results demonstrated that SEPs during V2 skiing can be used to quantify the cortical processing of somatosensory afferent input. Further studies are needed to show how the EEG responses are modulated according to the individual task-related skills and/or over time to skiing training.

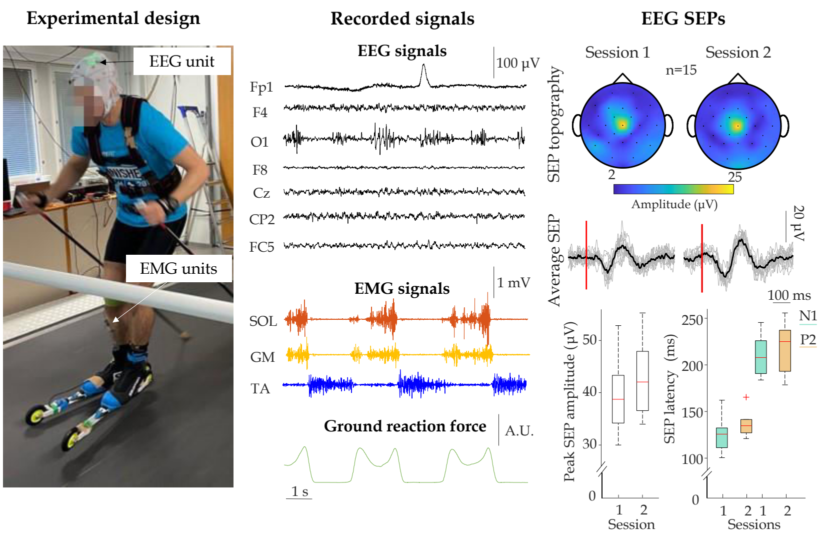


Figure 1 – Design and results. Left: treadmill setup. Middle: examples of recorded raw EEG, EMG and ground-reaction force signals in one representative participant. Right: SEP topography and average (n=15 stimuli) for one participant, and group level peak amplitude and latency for the SEPs in both sessions.

REFERENCES:

[1] Müller et al., 2011, Scand J Med Sci Sports.
[2] Pötzelsberger B et al., 2015, Scand J Med Sci Sports.
[3] Cerone et al., 2021, IEEE TNSRE.

PHYSIOLOGICAL DEMANDS AND PERFORMANCE PREDICTORS OF OLYMPIC SKI-MOUNTAINEERING

Alessandro Fornasiero[1,2], Aldo Savoldelli[1,3], Michele Mattivi[1,4], Tobia Forrer[1,4], Beatrice Todesco[1,4], Giorgia Cuniberti [1,4], Alexa Callovini[1,4], Federico Schena[1,4], Hans-Christer Holmberg[5,6], Barbara Pellegrini[1,2], Lorenzo Bortolan[1,2]*

[1] CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy [2]Department of Engineering for Innovation Medicine, University of Verona, Verona, Italy [3]CIBIO, University of Trento, Trento, Italy [4]Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy [5]Department of Health Sciences, Luleå University of Technology, Luleå, Sweden [6]Department of Physiology and Pharmacology, Biomedicum C5, Karolinska Institutet, Stockholm, Sweden

Keywords: Olympics, Ski-mountaineering, Performance

INTRODUCTION: The 2026 Milano-Cortina Winter Olympics will mark the debut of ski mountaineering, featuring two distinct competition formats: the Sprint and the Mixed-Relay. To date, the physiological demands and the predictors of performance in these ski mountaineering disciplines remain largely unexplored [1,2]. The purpose of this study was to investigate the physiological demand and the predictors of performance in the two Olympic formats.

METHODS: 20 ski-mountaineers (11 F), competing in an ISMF WC event featuring the Sprint and the Mixed-Relay, completed a laboratory-based physiological evaluation, including ski mountaineering-specific maximal and supra-maximal (intensity >VO_{2max}) tests, with a sub-group of 10 (5 F) being monitored (i.e., heart rate, blood lactate and rate of perceived exertion) during the races. Performance data of the participants in the different sections of the races (i.e., uphill skiing, uphill on foot, transitions, and downhill skiing) were retrieved according to a previously adopted approach [2]. Correlation and stepwise multiple linear regression analyses were used to assess the impact of section times on overall race performance, as well as the relationships between physiological variables and performance.

RESULTS/DISCUSSION: Uphill skiing represented the majority of race time in both formats and accounted for most of the variance in performance (~80-90%), with transition times explaining almost all the remaining variance in performance (~10-15%). Similar and near-to-maximal cardiac (>95% HR_{max}) and perceptual responses were observed in the two formats, with a significantly higher contribution of lactic anaerobic metabolism in the Sprint than in the Mixed-Relay ($p<0.001$). A main predictor of performance was found for each race, i.e. the skiing speed at the second ventilatory threshold (VT2) in the Mixed-Relay (~84% and ~78% of variance explained in uphill skiing and overall time, respectively) and the maximal sustainable skiing speed over a 2-min effort in the Sprint (~98% and ~95%).

CONCLUSION: To compete in Olympic ski mountaineering disciplines, athletes should improve their ability to replicate high-intensity efforts in the uphill sections of the races and refine their transition skills. Athletes should tailor their training considering the specific physiological demands of each race, emphasizing near-maximal to maximal intensities (from VT2 to VO_{2max}) for the Mixed Relay and supra-maximal intensities (>VO_{2max}) for the Sprint.

[1] Bortolan L., Savoldelli A., Pellegrini , B., Modena, R., Sacchi, M., Holmberg H. C., & Supej M. (2021). Ski mountaineering: perspectives on a novel sport to be introduced at the 2026 Winter Olympic Games. Frontiers in physiology, 12, 737249.

[2] Fornasiero, A., Fornoni, S., Callovini, A., Todesco, B., Savoldelli A., Schena, F., ... & Bortolan L. (2023). Analysis of Sprint Ski Mountaineering Performance. International Journal of Sports Physiology and Performance, 19(2), 155-163.

NEAR-INFRARED-SPECTROSCOPY DERIVED VS LACTATE THRESHOLDS IN ELITE NORDIC SKIERS

Jonas Forot [1,2,3], Forrest Schorderet [3], Cyril Burdet [1], Franck Brocherie [4], Grégoire P. Millet [3]

[1] Scientific Department, Fédération Française de Ski, Annecy, France ; [2] Scientific Department, Centre National de ski Nordique et de Moyenne Montagne, Prémanon, France ; [3] Institute of Sport Sciences, University of Lausanne, Switzerland ; [4] Laboratory Sport, Expertise and Performance (EA 7370), French Institute of Sport (INSEP), Paris

Keywords: near-infrared spectroscopy (NIRS), lactate thresholds, elite athletes, cross-country ski, biathlon, sex-differences.

INTRODUCTION: Cross-country skiing and biathlon are endurance sports that require an accurate exercise intensity prescription to optimize performance. Traditional methods for monitoring exercise intensities (e.g., lactate or heart rate) have limitations in terms of comfort and precision during on-field training. Recently, near-infrared spectroscopy (NIRS) has emerged as a new method for non-invasive monitoring of muscle oxygenation. The Moxy Monitor, a portable NIRS device, was shown to enable accurate determination of thresholds, when compared to lactate thresholds [1]. However, to date, the optimal location of the sensor remains unknown, particularly in sports as Nordic ski using both upper- and lower limbs. Therefore, this study aimed to evaluate the feasibility and accuracy of using NIRS to determine breakpoints (i.e. BP1 and BP2) compared to first (LT1) and second (LT2) lactate thresholds and to compare different muscle sites in male and female elite cross-country skiers and biathletes.

METHODS: Fifty-two athletes (29 males, 23 females) from the French national teams were recruited performed an incremental treadmill test on roller skis, with 3-minute work intervals at increasing speeds until exhaustion, interspersed with 30-s rest for lactate measurement (Lactate Pro 2). NIRS sensors were located simultaneously on four muscle sites: vastus lateralis, hamstrings, biceps, and triceps. Oxygen saturation (SmO2) was collected and analyzed to detect BP1 and BP2 [2] and compared to LT1 and LT2. Statistical analysis included repeated measures ANOVA and Chi-Square tests.

RESULTS/DISCUSSION: There are three key findings: First, the detection of BP1 is not effective due to insufficient precision, making it unsuitable for practical use. Second, it was possible to detect efficiently BP2 in vastus lateralis (88.5%), hamstrings (96.2%) and biceps (86.5%) but not in the triceps (24.1%). Third, there was a very good accuracy (i.e., bias [95% confidence intervals] in heart rate between BP2 and LT2) in the three muscles: vastus lateralis (-0.55 bpm [-8.85; 7.75]), hamstrings (1.3 bpm [-2.8; 4.2]) and biceps (1.0 bpm [-7.5; 9.5]). Finally, no significant differences were found between male and female athletes in the second threshold determination, likely due to the athletes' low adipose tissue thickness.

CONCLUSION: NIRS technology shows potential as a practical field tool for detecting the second lactate threshold in elite Nordic skiers. Its non-invasive nature and ease of use make it a valuable addition to traditional methods like lactate testing. However, improvement in the precision of BP1 detection is necessary for broader application. Further investigation should focus on NIRS as a device for monitoring training intensity during on-field training sessions, exploring its potential for real-time application in elite sport.

REFERENCES:

[1] Kirby BS, Clark DA, Bradley EM, Wilkins BW (2021) The balance of muscle oxygen supply and demand reveals critical metabolic rate and predicts time to exhaustion. J App Physiol

[2] Batterson, P. M., Kirby, B. S., Hasselmann, G., & Feldmann, A. (2023). Muscle oxygen saturation rates coincide with lactate-based exercise thresholds. Eur J Appl Physiol

ELECTROMYOGRAPHIC THRESHOLDS ARE EXPRESSED IN THE DOUBLE-POLING TEST IN CROSS-COUNTRY SKIERS

Masaki Takeda[1], Shunya Uda[1], Wako Kajiwara[1], Hirosih Nakano[1], Ryoji Horimoto[1], Naoto Miyamoto[2], Vesa Linnamo[3]*

[1] Graduate School of Health and Sports Science, Doshisha University, Kyotanabe, Japan, [2]NICHe, Tohoku University, Sendai, Japan, [3] Faculty of Sport and Health Sciences, University of Jyväskylä, FI-40014 Jyväskylä, Finland

Keywords: EMG Threshold, double-poling, cross-country ski

INTRODUCTION: Since double-poling in cross-country skiing requires significant power during the poling motion, muscle endurance and high muscle power are essential. The upper body may rely more on muscle power and endurance than the lower body, where endurance is more critical [1]. It is known that there is a threshold in muscle activity, EMGT (electromyographic threshold), during incremental exercise [2]. Two break points (EMGT1 and EMGT2) are recognized for EMGT [3]. However, there are no reports on whether EMGT of muscles for double-poling is detected in the progressive test. This study investigates whether EMGT is observed in muscles for double-poling in the progressive exercise test and, if so, how it is related to other physiological parameters.

METHODS: We conducted a double-poling test using roller skis (classical type, Marwe) on a treadmill with one World Cup-level cross-country skier. During the test, surface electromyography (EMG) was recorded for three upper body muscles (triceps brachii, posterior deltoid, latissimus dorsi) and two lower body muscles (vastus lateralis, gastrocnemius). Respiratory gas exchange parameters were also measured, while blood lactate concentration was only measured before and after the test. The exercise protocol involved maintaining a constant speed of 10 km/h while increasing the incline by 1° (approximately 1.75%) every minute, starting from 1°. EMGs were expressed as moving averages every 1000 msec after rectification. The thresholds were determined through visual inspection.

RESULTS/DISCUSSION: The exercise duration of the double-poling test was 8.5 minutes. An evaluation of the changes in the EMG revealed EMGT1 and EMGT2 in all muscle groups except the gastrocnemius muscle (Fig. 1). For the triceps brachii, a breakpoint corresponding to EMGT1 was observed at 6 minutes (7° incline, approximately 12.3%), and another corresponding to EMGT2 was observed at 8 minutes (9° incline, approximately 15.8%). Although slight breakpoints were observed in the respiratory gas exchange parameters, especially in ventilation and carbon dioxide output, they were not necessarily distinct.

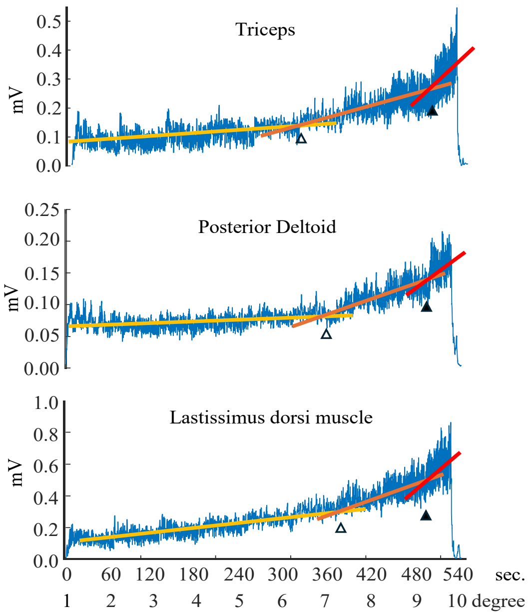


Fig. 1 EMG threshold 1 (△) and EMG threshold 2 (▲) during progressive double-poling test on roller ski.

CONCLUSION: The incremental exercise test using roller skiing double-poling clearly revealed the presence of EMGT1 and EMGT2, which were less related to changes in expiratory gas variables.

REFERENCES:

[1] Alsobrook, NG. and Heil, DP. 2009, Eur. J. Appl. Physiol.,105: 633–641
[2] Moritani, T. et al.,1993, J. Appl/ Physiol., 74: 1729-1734.
[3] Peter E. et al., 2016 J. Electromyogr. Kinesiol. 30: 216-230

WHOLE-BODY VIBRATION TRANSMISSION DURING RESISTANCE VIBRATION EXERCISE AND ARTIFICIAL GRAVITY: A "ski simulator" as a potential exercise device for the mission to Mars

Riccardo G. Sorrentino[1,2], Matej Supej[3], Nina Verdel[3], Ursa Ciuha[1], Igor B. Mekjavic[1]

[1]Department of Automatics, Biocybernetics and Robotics, Jozef Stefan Institute, Ljubljana, Slovenia, [2]Jozef Stefan International Postgraduate School, Jamova cesta 39, 1000 Ljubljana, Slovenia; [3]Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia

Keywords: whole-body vibration, vibration transmission, artificial gravity, vibration exercise

INTRODUCTION: Exposure to microgravity causes the loss of muscle and bone loss. To counteract this adaptive response to weightlessness a variety of exercise strategies have been introduced on the International Space Station. Preparations for deep space missions include considering artificial gravity in combination with resistance vibration exercise (RVE) as an exercise countermeasure. Squat exercise while exposed to vibration either without, or with artificial gravity (AG), is currently being investigated as a potential countermeasure for future space missions. The ground reaction forces and vibrations experienced by participants conducting RVE simulates those reported for skiing [1,2]. This study assessed the transmission of vibration during upright RVE (URVE) and RVE with AG (AGRVE).

METHODS: Two groups of male participants performed four sets of twelve repetitions of squatting in the upright position (URVE, N = 8) and in the horizontal position on a short-arm human centrifugation (AGRVE, N = 7). Both groups experienced whole-body vibrations (frequency=20 Hz, displacement=3.5 mm). RMS data was obtained with a Dewesoft[tm] system and with three Dytran[tm] accelerometers, two strapped on participants' lower back (L5 vertebra) and forehead and one on the vibration plate. Statistical analysis was performed with GraphPad Prism. Group comparisons were conducted with a mixed-model effect analysis.

RESULTS: Vibration transmission was dampened by lower limbs in both groups ($p < 0.0001$). No further mitigation happened between pelvis and head. AGRVE foot/pelvis vibration transmission was lower compared to URVE ($p = 0.0005$) while pelvis/head transmission was higher ($p = 0.004$).

CONCLUSION:

Vibration transmission is significantly lower during AGRVE compared to URVE.

ACKNOWLEDGEMENTS

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REFERENCES:

[1] Supej, M.; Ogrin, J. Transmissibility of Whole-Body Vibrations and Injury Risk in Alpine Skiing. J Sci Med Sport 2019, 22, S71–S77, doi:10.1016/j.jsams.2019.02.005.

[2] Supej, M.; Ogrin, J.; Holmberg, H.C. Whole-Body Vibrations Associated with Alpine Skiing: A Risk Factor for Low Back Pain? Front Psychiatry 2018, 9, doi:10.3389/fphys.2018.00204.

A COMPARISON OF THE WITHIN SESSION RELIABILITY OF FORCE-VELOCITY PROFILING METHODS USING LINEAR POSITION TRANSDUCERS IN WINTER SPORTS.

Cory Snyder [1,2], *Thomas Stöggl* [1,2]

[1] Red Bull Athlete Performance Center, Thalgau, Austria [2] Department of Sport and Exercise Science, Universität Salzburg, Salzburg, Austria

Keywords: Jumping, Testing, Skiing

INTRODUCTION: Force-Velocity profiling (FVP) is a popular tool for measuring physical performance and monitoring training adaptations in winter-sports [1]. Although useful, there are conflicting views on the reliability of FVP parameters, especially theoretical maximum velocity at zero force (V_0) [2]. Critically, the reliability of the input profiling parameters (mean force and mean velocity F_{mean}, V_{mean}) is a critical determinant of the reliability for the overall profile. Therefore, the purpose of the current study was to evaluate within-test reliability of individual FVP parameters in elite winter-sport athletes using the Lifter (Intelligent Motion, Wartburg an der Krems, Austria) device. Additionally, as the input parameters F_{mean} and V_{mean} are sensitive to the determination of the start and stop thresholds [2], therefore the current study also compared various methods to calculate profiling parameters and timepoints, as well as the resulting FV profiles to determine optimal methods for use on the Lifter device.

METHODS: As part of routine testing between 2022 - 2024, 18 athletes (world-class alpine, cross-country, biathalon, and ski jumping athletes) underwent FVP profiling using loaded jumps on the Lifter. Participants completed four repetitions at loads between 40-100% body weight. Profiling parameters for each repetition were calculated using the estimated force and velocity curves and various triggers of the start and end timepoints, as well as the method proposed by Samozino et al [3]. Within-session reliability for F_{mean}, V_{mean},and P_{mean} was assessed using coefficient of variability (CV) and intra class correlation coefficients. FVP profiles were calculated for each method (F_0, V_0, P_{max}, Sfv, r^2).

RESULTS/DISCUSSION: All selected methods presented strong ICC's (P_{mean} 0.93 -0.97, V_{mean} 0.95- 0.98, F_{mean} 0.89 – 0.99) and acceptable CV's (P_{mean} 3.0-6.5%, V_{mean} 2.4-4.6%, F_{mean} 0.7-3.5%). As all methods displayed high ICC's, the method with the lowest CV for P_{mean} was the Samozino method, using maximum velocity as the end (for the calculation of jump height) and the first velocity over 0.03 m/s as the start(to set push-off height) (3.03 ± 1.55%). Despite high within-session reliability, estimated FVP parameters for the same test varied up to 180% of the average value depending on the method used (ex. V_0 2.55 – 15.88 m/s for one athlete with r^2 > 0.88 for all methods – mean, 0.96). While all triggering methods present high reliability, the resulting output parameters do not produce the same profiling results This method displayed the lowest FVP P_{max} however, highlighting the need for further work to identify the method with the best combination of reliability and accuracy.

CONCLUSION: When using the Lifter, all of the selected methods displayed acceptable reliability, however large differences in the resulting FVP profiles were observed. Special care must be given to choosing which methods to use during FVP, as the output parameters are extremely sensitive to the variation of the input parameters, despite the appearance of high reliability.

REFERENCES:

[1] Cross, M. et al, 2021 Scand J Med & Sci in Sport
[2] Valenzula, P et al, 2021 Int J of Sport Phys & Perf
[3] Samozino, et al, 2008 J Biomech

LABORATORY AND FIELD TESTING INTEGRATION FOR A BETTER UNDERSTANDING OF BIATHLON PERFORMANCE

Chiara Zoppirolli

CeRiSM (Research Center in Sport Mountain and Heath), University of Verona, Rovereto, Italy

Department of Engineering for Innovation Medicine, University of Verona, Italy

Biathlon is a winter sport discipline that combine skating cross-country skiing and prone/standing rifle shooting. Skiing performance consists in 3 to 5 laps (duration 5 to 8 min, depending on race format) while carrying the rifle, 2 to 4 shooting series with 5 targets each placed 50 m away within the shooting range, and eventual penalty loops (75 or 150 m) in case of missed targets. Easy to understand how biathlon requires elevated physiological demands but also fine motor control to be able to shoot accurately and quickly, in conditions of high physical and mental stress. In long-term training programming, high-level biathlon coaches need updated scientific knowledge to provide right physiological, coordinative and technical stimuli to develop and improve all the components that are basic for biathlon performance. As an endurance discipline, aerobic capacity (V'O2max and its fractional utilization), anaerobic capacity (the anaerobic contribution to maximum mechanical power production) and exercise economy (particularly important in sports with high technical component) are important performance determinants. However, biathlon is a peculiar intermittent endurance sport, with moderate performance duration and the need to smartly control the physiological effort prior to shooting. Predictive models revealed that speed and $V'O_2$ at 2 and 4 mMol/L as well as skiing economy are the physiological parameters that mostly explain the variability of biathlon performance, after shooting accuracy (Jonas 2022). From a biomechanical perspective, shooting accuracy in high-level biathlon was related to the ability to control the athlete-rifle stability while aiming and just after the shoot release. High hold stability, cleaness of triggering and reduced center of mass displacement across the shooting direction, were all related to high shooting performance. The aim of the present invited speech is to understand what are the best laboratory testing routines for high-level biathlets in order to monitor the effect of regulat training or particular training regims, by looking at the literture but also trying to think about new testing routines that give a complete assessment of the biathlet. In particular, another issue is to provide evidences to understand the need for the development of field testing routines to integrate laboratory assessment and improving the understanding of both biathlon performance and athlete development. The principal scientific questions that seem to be important to face could be related to different fields such as the physiological effect of skiing and training on different terrains, the physiological and biomechanical effect of skiing and training with or without the rifle, the understanding of better individual balance between intensity distribution and shooting performance for prone or standing series, the effect of particular strength training regimes on upper body strength, gear distributuion and strategies of polìng force application while skiing with the rifle. Again, as far as concerns shooting, filed testing should help in understand and improve shooting approach in different conditions (different positions, exercise effort, respiration patterns or stressors such as the presence of opponents or the noise). These themes are of particular interest for high-level biathlon and maybe should deserve a scientific in-depth analysis in the next future, integrating laboratory and filed testing routines.

REFERENCES:

[1] Laaksonen & Holmberg (2018), Front. Physiol. 9:796;
[2] Kårström et al (2022), J Sports Sci, 40:24, 2722-2731 ;
[3] Jones et al (2023), Int J Sports Physiol and Perf.

A STATIC HOLD TEST CAN ASSESS STABILITY OF HOLD AND POSTURAL CONTROL FOR BIATHLON PRONE SHOOTING

Miika Köykkä[1,2],, Keijo Ruotsalainen[1], Vesa Linnamo[1]*

[1] Sport Technology Unit, Faculty of Sport and Health Sciences, University of Jyväskylä, Vuokatti, Finland [2] Finnish Institute of High Performance Sport KIHU, Jyväskylä, Finland

Keywords: performance, technique, testing, rifle shooting

INTRODUCTION: In the prone shooting posture, biathletes rely on both elbows and the lower body for support, and stability of hold is a key factor for successful shooting [1, 2]. Biathletes often adjust rifle settings and postures to optimise performance and engage in numerous dry shooting sessions [3], sometimes focusing on static stability of hold. However, the roles of postural control and isolated stability of hold have yet to be explored. Thus, this study examined 1) associations between stability of hold, postural control, and shooting performance, and 2) whether key measures in prone shooting correlate with those in a static hold test.

METHODS: 27 biathletes (11 females; age 20.1 ± 3.6 years, biathlon experience 8.1 ± 3.1 years) completed a static holding test (HT) and a biathlon shooting test (ST) in the prone posture. HT consisted of 4×45-second periods with 30-second breaks, including two 10-second holds while aiming at a target and holding their breath. ST involved 6×5 dry shots mimicking competition technique and rhythm in a resting state. Aiming point trajectory (Aim) and shooting performance (Hit_{dist}, hit point distance from the centre of the target) were measured using an optoelectronic Noptel device, while centre of pressure (COP) under the front (F) and rear elbows was measured using force platforms. The shortest 5-second Aim and COP traces were analysed from the 10-second holds in HT, while the last 0.6 seconds before triggering was analysed from each shot in ST. Stability of hold and postural control were assessed using standard deviation (SD) and mean velocity (MV) in left-right (X) and up-down (for Aim) or forwards-backwards (for COP) (Y) directions, 95% confidence ellipse area (CEA), and mean resultant velocity (R MV). Natural logarithm transformations were applied to non-normal data, and Pearson correlations were computed to examine associations.

RESULTS/DISCUSSION: In ST, correlations to Hit_{dist} were found in most stability of hold and front arm postural control measures (Table 1). This reinforces the importance of stability of hold in biathlon prone shooting and suggests front arm postural control may also be important. COP F Y SD was linked to Aim R MV, Y MV, and CEA (R = .39 to .45, P < .05), implying that front arm control may influence stability of hold but could also play an independent role. These measures during ST strongly correlated with their HT counterparts (Table 1), suggesting HT can assess stability of hold and postural control for the needs of biathlon prone shooting.

Table 1. Correlations to Hit_{dist} in ST and between corresponding HT and ST measures

	Corr to Hit_{dist} in ST	Corr HT to ST
Aim R MV	R = .50 [.15, .74]**	R = .90 [.78, .95]***
Aim X MV	R = .53 [.19, .76]**	R = .80 [.60, .90]***
Aim X SD	R = .57 [.25, .78]**	R = .64 [.34, .82]***
Aim Y MV	R = .39 [.01, .67]*	R = .94 [.87, .97]***
Aim CEA	R = .51 [.15, .74]**	R = .60 [.28, .80]**
COP F Y MV	R = .40 [.02, .68]*	R = .90 [.79, .95]***
COP F Y SD	R = .51 [.17, .75]**	R = .68 [.40, .84]***

Corr correlation, *** p < .001, ** p < .01, * p < .05

CONCLUSION: Along with stability of hold, front arm postural control may contribute to successful biathlon prone shooting. The HT protocol offers a practical way to assess stability of hold and postural control for biathlon prone shooting. It provides insights for athletes and coaches, helping to evaluate shooting posture adjustments and track training progress.

REFERENCES:

[1] Sattlecker, G et al, 2017 Int J Sports Physiol Perform
[2] Köykkä, M et al, 2022 Scand J Med Sci Sports
[3] Laaksonen, M et al, 2018 Front Physiol

PHYSIOLOGIC EFFECTS OF CHANGING RIFLE CARRYING POSITION IN ELITE BIATHLETES

Ethan Livingood[*1], *Isaac Burgess*[1], *Gregory Marshall*[1], *James Becker*[1]

[1]Department of Kinesiology, Montana State University, Bozeman MT, USA

Keywords: Biathlon, Efficiency, Equipment Modification, Harness

INTRODUCTION: Skiing while carrying the additional mass of a rifle has detrimental effects on both physiologic and biomechanical measures of skiing performance [1,2]. However, it may be possible to offset these detrimental impacts by manipulating the position of the rifle on the athlete's back or the tightness of the harness. While this has been considered in theoretical studies [3], to date it has not been investigated experimentally. Therefore, the primary purpose of this study was to evaluate the impact of changing rifle position and harness tightness on physiologic response during skiing in elite biathletes. Secondarily, we also examined whether harness position and tightness influences shooting timing.

METHODS: Eight members of the US Biathlon National Team participated in this study. On day one athletes performed an incremental step test to determine maximal oxygen consumption (VO_2 max). On day two athletes skied three-minute intervals wearing their rifle in their habitual harness position (HAB), followed, in a randomized order, by combinations of rifle high or low on their back and harness tight or loose (HL, HT, LT, LL). Oxygen consumption (VO_2) was averaged over the last minute of each interval and used to calculate gross efficiency (GE) and economy (E). Tidal volume (VT) and minute ventilation (VE) were also calculated to examine effects of harness on breathing patterns. Following each interval athletes performed a dryfire shooting bout in standing position which was recorded by highspeed video to assess how harness position influenced time to get into and out of shooting position. Linear mixed effects models with Bonferroni corrected pairwise comparisons were used to assess effect of harness condition.

RESULTS/DISCUSSION: There were significant fixed effects of condition for VO_2 ($p = 0.026$), GE ($p = .003$), and E ($p = .007$). Pairwise comparisons showed that VO_2 was lower ($p = .045$) while both GE ($p = .001$) and E ($p = .004$) were higher in the HT condition than HAB condition. The HT condition may move the center of mass of the athlete-rifle system into a more advantageous forward lean position, thus increasing skiing efficiency. There were no significant fixed effects of condition for any of the other variables (all $p > .05$) suggesting that moving and especially tightening the harness did not impact breathing while skiing or ability to get into and out of shooting position quickly.

Table 1. Mean and standard deviation of physiologic variables. * indicates significantly different from habitual.

Condition	Habitual	High Loose	High Tight	Low Tight	Low Loose
VO_2 (ml/min/kg)	63.1 ± 6.4	61.6 ± 7.4	60.8 ± 7.7*	61.9 ± 6.4	61.1 ± 6.6
VT (L/breath)	2.8 ± 0.6	2.7 ± 0.6	2.6 ± 0.6	2.7 ± 0.5	2.6 ± 0.6
VE (L/min)	127.0 ± 17.5	131.0 ± 19.0	127.0 ± 19.1	131.0 ± 19.3	130.0 ± 16.4
GE (%)	17.0 ± 0.6	17.4 ± 0.9	17.8 ± 0.7*	17.4 ± 0.4	17.5 ± 0.6
E (% VO_2 max)	87.0 ± 6.6	84.8 ± 7.7	83.6 ± 6.5*	85.1 ± 4.1	84.1 ± 5.2

CONCLUSION: Athletes may be able to offset the negative impacts of the weight of the rifle by manipulating the position of the rifle on their back and/or the tightness of the harness.

REFERENCES:

[1] Stöggl, T et al, 2015. Med Sci Sports Exerc, 47(3), pp 617-624.
[2] Kårström, M et al, 2019. Front Physiol, 10:1519.
[3] Frederick, N, 1987. Int J Sport Biomech, 3, pp 392-403.

VISUAL REQUIREMENTS AND SHOOTING PERFORMANCE OF THE ELITE BIATHLETE

Zöe L. Wimshurst [1], Miika Köykkä [2,3], Keijo Ruotsalainen [3], Vesa Linnamo [3]*

[1] School of Health and Rehabilitation Sciences, Health Sciences University, UK, [2] Finnish Institute of High Performance Sport KIHU, Jyväskylä, Finland [3] Vuokatti Sports Technology Unit, Faculty of Sport and Health Sciences, University of Jyväskylä, Finland

Keywords: biathlon, vision, rifle shooting, skill training

INTRODUCTION: Sports vision is a growing area of interest with increasing numbers of high-performing teams dedicating time to test and train their visual system to improve competitive performance. However, the visual system consists of several components, or "visual skills," each of varying importance for sports and activities. Currently, there is no systematic way to determine which visual skills are most relevant for each sport. In a previous study, elite air rifle shooters demonstrated higher levels of accommodation than non-elite shooters, and all shooters had better visual acuity than non-athletes [1]. Yet, the study did not explain why the visual capabilities that they tested were considered crucial for shooting. This study aimed to design and use a questionnaire to identify which visual skills those involved in biathlon perceive to be important for sport's shooting element and to test whether these identified visual skills correlate with key shooting technical components [2] and shooting performance in biathletes.

METHODS: Fifty-six participants (36 athletes, 18 coaches, 2 others) completed the questionnaire, and the visual skills rated most important by athletes and coaches were selected for phase two of the study. The six visual skills identified by the athletes/coaches (Static Visual Acuity, Eye-Hand Co-ordination, Attention, Visual Reaction Time, Visual Concentration, Central-Peripheral Awareness) plus two identified as potentially important by the researcher ZLW (Gaze Stability and Saccadic Eye Movements) were tested in a group of 27 biathletes. Without physical stress, athletes also undertook tests of biathlon prone shooting performance (Hit_{dist}: the hit point's distance from the centre of the target) and shooting technical components, including Aiming Accuracy (COG_{dist}: the distance between the aiming point's mean location and the target 0.6-0.0 s before triggering), Stability of Hold ($R\ MV_{02}$: mean resultant velocity 0.2-0.0 s before triggering; Y SD: vertical standard deviation 0.6-0.0 s before triggering), Cleanness of Triggering (COG2Hit: the distance between the hit point and the aiming point's mean location 0.6-0.0 s before triggering), and Timing of Triggering ($TIRE_6$: an index score, from 1 to 6, based on 0.1-second time intervals from 0.6 to 0.0 seconds before triggering, where a smaller distance between the aiming point and the target is represented by a higher score). Pearson (Rp) and Spearman (Rs) correlations were used for normally and non-normally distributed variables, respectively.

RESULTS: Saccadic Eye-Movements correlated with Hit_{dist} (Rp = .54, P = .004), COG_{dist} (Rp = -.41, P = .033), $R\ MV_{02}$ (Rp = -.43, P = .026), Y SD (Rp = -.38, P = .048) and COG2Hit (Rs = -.47, P = .014). In the Peripheral Awareness test, errors correlated with COG2Hit (Rs = .51, P = .006) and $TIRE_6$ (Rs = .46, P = .015). In the Concentration test, missed reactions correlated with $R\ MV_{02}$ (Rp = .40, P = .039) and Y SD (Rp = .43, P = .024). In the Gaze Stability test, time to first fixation correlated with $R\ MV_{02}$ (Rs = -.50, P = .011) and $TIRE_6$ (Rs = .51, P = .008).

CONCLUSIONS: Clear links exist between some visual skills and shooting performance. However, the questionnaire may not be the best method of discovering which visual skills are important to a given sport, as the coaches and athletes did not identify the most relevant skills. Future recommendations include follow-up training studies including also fatigue aspect using Saccadic Eye Movement training as a tool to enhance shooting performance in biathletes.

REFERENCES:
[1] Mon-López, D et al, 2022 Eur J Sport Sci
[2] Köykkä, M et al, 2022 Scand J Med Sci Sports

ROLLER SKI INTERVAL TRAINING IN BIATHLETES: ASSESSING WHETHER ATHLETES MEET HIGH-INTENSITY TARGETS ON THE TRACK

Bettega S.[1,2], Pellegrini B.[1,3], Schena F.[1,2], Zoppirolli C.[1,3]

[1]CeRiSM, (Research Center Sport Mountain and Health), University of Verona and Trento, Rovereto, Italy
[2]Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Italy
[3]Department of Engineering for Innovation Medicine, University of Verona, Italy

INTRODUCTION: Biathlon is a unique discipline that combines cross-country skiing with shooting, requiring athletes to excel in both high-intensity physical exertion and precision. Training regimen of these athletes often includes high-intensity sessions, either combined with shooting or performed on roller ski tracks for convenience. Training on uphill terrain can effectively target specific physiological demands. However, the variability of curves, inclines, and declines makes it challenging to maintain a consistent intensity throughout the workout. The aim of this project is to analyze the physiological effects of two types of high-intensity training on a ski track, focusing on oxygen consumption (VO_2) and comparing it to heart rate (HR), which is commonly used for training prescription and monitoring, alongside measured lactate levels.

METHODS: Five elite athletes (4M, 1F) participated in this study (age: 25.5±4.5 years, weight: 71.4±8.6 kg, height: 173.2±9.0 cm, VO_2max: 67.1±8.5 ml/min/kg). Athletes first completed a lab test with two phases: (i) a 5-minute incremental step test with 2-minute recovery intervals, designed to determine exercise intensities and lactate thresholds (2, 3, 4 mmol/L), followed by (ii) a rapid ramp test with increasing mechanical power every 30 seconds to exhaustion to determine VO_2max. Both tests measured gas exchange via a metabolic cart. The following week, athletes performed two roller-skiing training sessions on a 2 km track: 5 × 2 km intervals at Z5 intensity (1:1 work-to-rest ratio) on the first day, and 3 × 6 km intervals at race pace with 10 minutes recovery on the second day. The second session included sprint simulations and continuous intervals. Gas exchange (ml/min), heart rate (bpm), and blood lactate ([La-, mmol/L]) were measured during both sessions. Time spent in each training zone was calculated from lab results (HR% and VO_2% time). Intensity distributions were analyzed using a Friedman Test, and a paired Student's t-test compared the time spent in the same intensity zone between HR and VO_2 within the same session. Statistical significance was set at $P < 0.05$, and data are presented as mean ± SD.

RESULTS: In Training 1, significant differences were found in the time spent across different HR and VO_2 intensity zones (both $p < 0.001$). The t-test results revealed significant differences between HR and VO_2 in several intensity zones. Specifically, significant differences were observed in Z1 ($p < 0.001$), Z3 ($p < 0.001$), and Z4 ($p < 0.001$). A smaller but significant difference was also found in Z2 ($p = 0.029$). Athletes spent more time in Z4 for HR (58±12%) compared to VO_2 (11±18%), whereas more time was spent in Z5 for VO_2 (54±17%) than HR (14±12%). For Training 2, we have complete data for only 3 athletes. The intensity distribution across training zones differs for both HR and VO_2 ($p < 0.01$ and $p = 0.020$, respectively). A paired t-test comparison showed significant differences between HR and VO_2 in Z1 ($p < 0.001$), Z3 ($p = 0.003$), Z4 ($p = 0.005$), and Z5 ($p = 0.007$), while no significant difference was found in Z2 ($p = 0.338$). Athletes spent more time in Z3 for HR (30±10%) compared to VO_2 (14±8%), and more time in Z4 for HR (49±4%) compared to VO_2 (25±19%). In contrast, athletes spent more time in Z5 for VO_2 (38±30%) than HR (9±9%). The time spent above 90% VO_2max also varied greatly between athletes during both training session, with 970 ± 387 seconds in Training 1 and 1223 ± 948 seconds in Training 2.

CONCLUSIONS: Despite similar time distribution in HR zones and comparable lactate levels at the end of the training sessions, athletes showed differences in the distribution of time spent in VO_2 zones, with more pronounced variability in the time spent above 90% VO_2max. This highlights the individual variability in high-intensity efforts, which is crucial for stimulating specific adaptations. Therefore, it is essential to consider the individual characteristics of athletes and adapt training protocols accordingly to ensure the necessary stimuli are achieved

MULTI-SEGMENT SKIER MODEL FOR SIMULATING FALLS AT HIGH SPEED

Piotr Aschenbrenner [1], Agnieszka Tomaszewska [2], Andrzej Ambroziak [2], Tomasz Grzywacz[1,3] , Wojciech Woźnica[4] , Marcin Krawczyński[1]

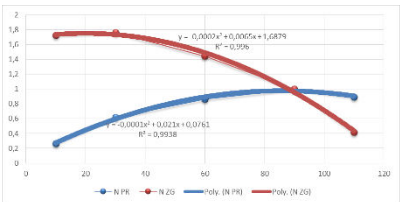
[1] Faculty of Physical Culture, Gdansk University of Physical Education and Sport, Gdansk, Poland [2] Department of Structural Mechanics, Faculty of Civil and Environmental Engineering, Gdańsk University of Technology, Gdańsk, Poland, [3]Polish Ski Association, [4]Wroclaw University of Health and Sport Science, Wroclaw, Poland

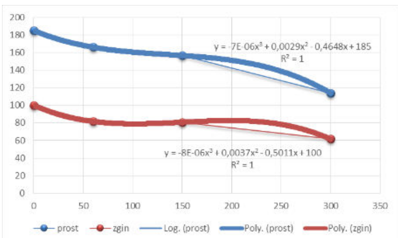
Keywords: accidents, inertia, moment of force in the joint

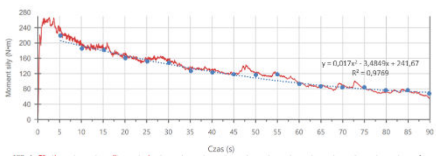
INTRODUCTION: Accidents during skiing competitions occur randomly, are not subject of any real-time measurements and cannot be repeated in real conditions. One of the methods of investigating accidents is computer simulation, which take into account the inertial and kinetic parameters of the object [1,2]. There are papers with human numerical models described in the literature [1,2] and commercial models, but they do not take into account the specifics of a skier on skis. Based on the literature review, it can be concluded that there is no available specification of a skier model with ski equipment, and therefore the authors set a goal to develop a multi-segment model of a skier with ski equipment.

METHODS: 20 national team athletes, seniors and juniors, in alpine skiing were examined. The research methods used were: body geometry measurements, muscle torque, ROM in joints, reaction time, using: BIODEX, BLINK PRO, Kistler. Standard research procedures according to the manufacturer's protocols. Computer modeling was carried out in accordance with the principles of multi-body dynamics, using commercial MSC ADAMS software. The factors taken into account were: 21 body elements as rigid elements; resistance points, bonds; external and internal forces. Nonlinear stiffness resulting from the dependence of muscle torque on joint angle, angular velocity and muscle activation time was assumed.

RESULTS/DISCUSSION: Based on measurements in isometric and isokinetic conditions, torque functions were determined depending on the angle, holding time and angular velocity in the joint. Example results for the knee joint, M as a function of angle,velocity and time: These data for individual joints and inertial values for individual links were entered into the kinetic parameters of the skier model.







$y = -0{,}0002x^2 + 0{,}0065x + 1{,}6879$ $y = -7E\text{-}06x^3 + 0{,}0029x^2 - 0{,}4648x + 185$ $y = 0{,}017x^2 - 3{,}4849x + 241{,}67$

CONCLUSION: The multi-segment model can help to better understand how parts of a skier's interact during accidents and can be used to identify risk factors.It still requires development.

ACKNOWLEDGEMENTS: Calculations were partially made using resourses of Centre of Informatics Tricity Academic Supercomputer and networK CI TASK. Co-financed by the Minister of Science under the "Regional Excellence Initiative" Program (RID).

REFERENCES:

[1] Carter EL, Neal-Sturgess CE (2009) MADYMO reconstruction of a real-world collision between a vehicle and cyclist. Int J Crashworthiness 14(4):379–390.
[2] Wdowicz, D., Ptak, M. Numerical Approaches to Pedestrian Impact Simulation with Human Body Models: A Review. Arch Computat Methods Eng 30, 4687–4709 (2023).

MOVEMENT FREQUENCY AND PERFORMANCE LEVEL DURING ALPINE SKIING AND TESTING EXERCISES IN YOUNG SKIERS

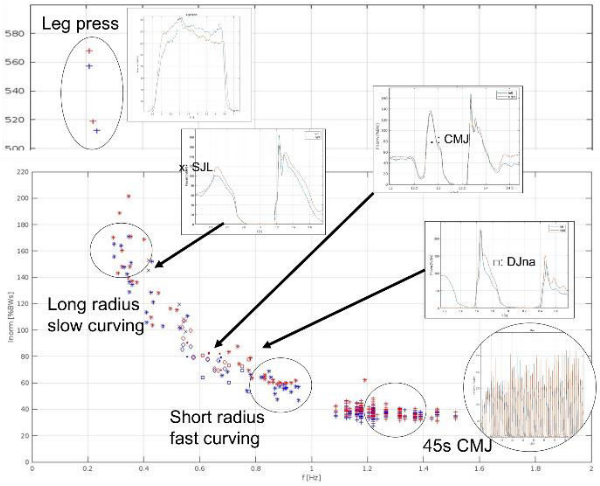
Andrea Besseghini[1], Arrigo Canclini[1], Antonio Canclini[2], Guido Baroni[2], Renzo Pozzo[1,3]

[1] LABIS-IIS ALBERTI, Bormio, Italy [2] Politecnico Milano, Italy [3] DDAME Un. Med., Udine, Italy

Keywords: Alpine skiing, Ground reaction force, Dryland training, Conditional testing

INTRODUCTION: Alpine skiing is influenced by a combination of physiological/functional parameters and psychological decision making. Factors such as muscular strength, balance, coordination, flexibility, anaerobic and aerobic capacities play a crucial role in alpine ski-racers performance (Andersen 1988; Turnbull 2009; Gorski 2014; Raschner 2017). The purpose of this study is to evaluate the most important capacities at the beginning of the dryland training program (May) and before the ski season (September) by the laboratory strength test . Furthermore, we measured the performance during the skiing races by video tape synchronized to the ground reaction force measurement by sensor insoles.

METHODS: Data collection in laboratory was performed in May and September 2023. Crono-Jump, Sensor insoles (Moticon ReGo AG) combined with leg press, trunk machine (Ochs,1998) and load cell combined with knee extension-flexion machine, were used. 20 athletes, 10 male (age: 17.9± 2.3 years, BW: 75.5 ± 10.6 kg) and 10 female (age: 17.6 ± 2 years, BW: 61.6 ± 8.6 kg), volunteered to participate in this study. All subjects are advanced alpine skiers belonging to the local ski club.



RESULTS/DISCUSSION: There are differences between May and September and also differences between male and female. Looking at the single subject it is possible to identify improvement thanks to the execution of specific exercise during summer.

Fig. 1 shows the normalized impulse of the force versus frequency of the motion for all tests (laboratory and on field). In the upper left corner we can find leg press (low frequency – high average force); in the lower right corner there is the 45s CMJ (high frequency – high peak force). In the middle of the graph, we can find single jump tests and the skiing test on the field (with different frequency of execution). Impulse values of turns with long radius (giant slalom) follow directly the values of leg press and precede single jump tests; Impulse values of turns with short radius (slalom) follow single jump tests and precede 45s CMJ.

CONCLUSION: Evaluation at the beginning of the dryland training program and before the ski season are very important to decide which type of training is better to improve performance, to evaluate the level of the athletes and, sometimes, to help to prevent injuries. Bosco test, leg press, knee machine and trunk machine allow to collect a series of repeatable data that are significant for the coaching strategy. Findings show that the laboratory tests are strongly correlated with the test on field. In this way, accurate testing procedures on field can be performed during the skiing season, in order to point out deficiencies to be improved which depend more on the physical or technical deficiency of the athletes.

REFERENCES:

[1] Raschner, C. et al.,2017. Proc.ICSS VII;
[2] Ochs, S., 1998, Sporttherapie

DIFFERENCES IN KINEMATIC PARAMETERS OF ALPINE SKIING TURNS BETWEEN SKIERS OF DIFFERENT SKILL LEVELS

[1]Vjekoslav Cigrovski, [1]Ivan Bon, [1]Mateja Očić, [1]Lana Ružić Švegl, [2]Matej Švegl*

[1]University of Zagreb, Faculty of Kinesiology
[2]High school for pharmacy, cosmetics, and healthcare

Keywords: kinematic analysis, ski technique, teaching process, alpine ski school

INTRODUCTION: For most recreational skiers, the goal is to acquire a level of skiing technique that allows them to independently and safely navigate all ski slopes. Recreational skiers typically conquer slopes by executing parallel turns (PT). This technique is applicable in almost all snow conditions and slopes. For a skier to have the ability to steer the skis in the desired direction, at the desired speed, maintain a stable stance, position the skis at the desired edge angle, and optimally regulate the pressure, they must perform certain specific skiing movements. These movements must be performed in a timely manner at a precisely defined phase of the turn to control the forces acting on the skier and guide the skis in the desired direction. The main unit which is continuously executed while skiing is the ski turn which can be divided in two or three distinct phases. Kinematic analysis can provide a clear insight in the complexity of each movement during different phases while performing a ski turn.

METHODS: The sample consisted of 23 ski instructors and 23 recreational level skiers. Analysis of kinematic parameters during performing PT was conducted using Xsens kinematic system. Testing protocol was carried out directly on the ski slope in defined corridor 15 m wide. Each participant performed 12 turns in observed element. The following kinematic variables were measured: hip flexion of the inside an outside leg, knee flexion of the inside an outside leg. The parameters were measured in 3 time points (phases) of the performed turn. One way ANOVA was used to determine differences in the observed parameters between two groups.

RESULTS/DISCUSSION: Observing the kinematic parameters, it is evident that in all three phases of the turn, there is a significant difference in certain variables between the two tested groups of subjects. It is noticeable that the group of subjects with a lower level of skill recorded less flexion in the observed joints in all phases of the turn. In the group of subjects with a higher level of skill, a greater range of motion in the joints was determined, from the beginning to the end (phases 1-3) of the turn. This is particularly evident in the second and third phases of the turn, where all observed kinematic variables significantly differ. The results confirmed significant differences in the specific movements between the skiers with higher and lower skill levels in PT. There are very few studies that conduct kinematic analyses and compare skiers of different skill levels within the recreational population. By identifying and understanding the relationships between different body segments, this research contributes to a deeper understanding of the mechanisms involved in controlling of the skis for skiers who are in the beginning process of learning skiing techniques.

CONCLUSIONS: These insights can positively influence the development of methodological approaches aimed at more effectively mastering skiing techniques, thereby improving ski school programs. Consequently, biomechanical analysis of recreational skiing can provide valuable information for better understanding the mechanisms of injuries in recreational skiers and their prevention.

REFERENCES:

[1] Neuwirth C. et al. 2020. Classification of alpine skiing styles using GNSS and inertial measurement units. Sensors, 20(15), 4232.

SMART COMPETITIONS IN ALPINE SKIING – A PILOT STUDY

Stefan Brügger [1,2], Michael Romann [1], Björn Bruhin [1,2]

Swiss Federal Institute of Sport Magglingen SFISM, Switzerland / [2]Swiss-Ski, Home of Snowsports, Worblaufen/Switzerland

Keywords: smart competitions, talent development, alpine skiing

INTRODUCTION: Junior alpine ski racing formats often mirror those of elite athletes like Marco Odermatt, but it's questionable whether they are age-appropriate and beneficial for younger competitors. Theodoulides and Armour (2001) note that sports competitions are typically structured by age groups, and many countries invest in youth sports to foster development. Coalter (2007) argues that effective formats should focus on talent and personality development. Building on this, Côté (2016) introduced the concept of "smart competition," which incorporates participation, personality, and performance in line with Lerner's (2003) development theory.

METHODS: 13 female ski racers and eight male ski racers (9.3 ± 0.9 years) took part in the pilot study. Using data from Global Navigation Satellite System sensors, both competition formats were analyzed using the parameters: Movement time inside and outside the competition, number of runs, turns taken and personal experience. The data were compared using Student's t-test, Wilcoxon rank test and Cohen's d effect sizes.

RESULTS/DISCUSSION: Significant differences were found for active movement time (1), competition time (2), number of runs (3) and curves (4) (p = < .000 (1); < .000 (2); < .000 (3); < .000 (4)). Using a questionnaire on the personal competition experience, a significant difference was found for enjoyment of the competition format (p = .020) with a mean effect size according to Cohen (d = 0.33).

	current competition format		optimized competition format		
	MV	SD	MV	SD	d (cohen)
active movement time [s]	228.61	23.58	640.25	61.52	**-0.98***
competition time [s]	67.6	9	316.5	40.22	**-0.97***
number of passes [n]	1.99	0.02	4.52	0.51	**-0.96***
number of curves [n]	39.86	0.48	123.81	17.52	**-0.96***

Notes. MV = mean value; SD = standard deviation; significant differences (p < .05) are highlighted in bold and marked with specific symbols (*).

CONCLUSION: In the optimized competition format, the active movement time was increased by 180%. The comparison of the development over time showed that the running time over the individual runs was improved in the optimized format. By optimizing the competition format, the examined parameters active movement time, competition time, number of runs and number of curves could be increased. *SO WHAT !?!* By increasing the active movement time in the competition, young athletes are given more time to be able to ski actively. Individual performance development is promoted by developing over more than just two runs. Furthermore, by increasing the number of runs and turns in the competition, technical skiing skills are promoted. The pilot study serves as the basis for the implication of a new competition format at Swiss-Ski.

REFERENCES:

Beck, J. et al. (2019). Selbstbestimmte Motivation im späten Kindesalter. *Zeitschrift für Sportpsychologie*, *26*(1).
Coalter, F. (2007). *A Wider Social Role for Sport: Who's Keeping the Score?*
Côté, J. etal. (2016). Evidence-based policies for youth sport programmes. *International Journal of Sport Policy and Politics*, *8*(1).
Lerner, R. et al. (2003). Positive Youth Development: Thriving as the Basis of Personhood and Civil Society. *Applied Developmental Science*, *7*(3).
Theodoulides, A. et al. (2001). Personal, Social and Moral Development through Team Games: Some Critical Questions. *European Physical Education Review*, *7*(1), 5–23.

INFLUENCE OF SPECIAL LIFE CIRCUMSTANCES ON THE RISK OF INJURY IN ALPINE SKIING - A STUDY OF ATHLETES ON THE GERMAN SKI ASSOCIATION'S DEVELOPMENT-TEAM

*Maren Goll [1], Lisa Thallmair [1], Andres Huber [3], Karlheinz Waibel [2], Peter Spitzenpfeil [1]

[1] Applied Sport Science, Technical University of Munich, Munich, Germany,[2] Olympiastützpunkt Bayern, Munich, Germany, [3] German Ski Association, Planegg, Germany

Keywords: injury prevention, development athletes

INTRODUCTION: Alpine skiing's high injury rates require new approaches to mitigate the risk of injury (1). For alpine skiing development athletes there is a lack of research regarding the sport-speficic risk factors (2) in both, internal and external factors (3, 1). The basis for appropriate measures consist of new insights into further internal and external risk factors and injury mechanisms (3). Therefore, the research question of this study was to examine life circumstances of development athletes who have sustained a major injury during one season.

METHODS: Due to their injury history, 13 development-team athletes were identified to participate in guided interviews. The interview items consisted of potential predictors influencing a higher injury risk and were defined in accordance with coaches' evaluation in order to gain insights into the experiential reality of the athletes (4). All interview data was categorized using qualitative content analysis by Mayring (5).

ID	m/f	Age	Type of injury
1	m	20	ACL rupture
2	f	18	ACL, MCL, LCL rupture, meniscus tear
3	m	17	Comminuted tibia fracture, fibula fracture, syndesmosis tear.
4	f	19	ACL rupture
5	f	19	ACL rupture
6	m	18	ACL rupture
7	f	17	Acromioclavicular fracture and dislocation
8	f	17	Craniocerebral injury
9	m	17	Tibia&fibula fracture
10	m	18	Thoracic vertebra fracture
11	m	18	Fibula fracture
12	m	17	ACL rupture
13	m	17	ACL partial rupture

Table 1 Participating athletes, gender, age and type of injury

RESULTS/DISCUSSION: The categories 1) external factors 2) psychological factors 3) physiological factors and 4) social circumstances revealed a potential association in their subcategories specifically for new equipment, stress/pressure and social relations with injury.

CONCLUSION: Paying attention to athletes' life circumstances, (unexpected) pressure situations or equipment changes might help mitigate injury risk.

REFERENCES:

[1] Bere, T. et al, 2014. Scand J Med Sci Sport
[2] Hildebrandt, C. et al, 2019. J SEMS
[3] Bahr, R. & Krosshaug, T, 2005. Brit J Sports Med
[4] Döring, N., & Bortz, J. (2016). Springer. Heidelberg.
[5] Mayring, P. (2019). Beltz. Weinheim.

MODIFICATIONS TO THE NANOINDENTATION TEST PLATFORM FOR MEASURING THE MECHANICAL PROPERTIES OF ICE AND COMPACTED SNOW

Karlis Agris Gross[1], Ude Hangen[2]

[1] Institute of Materials and Surface Engineering, Riga Technical University, Riga, Latvia [2] Bruker Nano Surfaces and Metrology Division, Aachen, Germany

Keywords: ice friction, skeleton, skiing, multifunctional testing

INTRODUCTION: Mechanical property determination of ice and compacted snow requires specialized equipment in subzero temperature conditions. While several approaches are available for measuring the ice friction, less test platforms offer the capability for assessing mechanical properties such as elastic modulus, hardness and creep. Given the transient properties of ice and snow, particularly at warmer subzero temperatures, it is valuable to measure as many different properties as possible on the same test volume within the same test environment. The objective is to a) evaluate a new testing approach for measuring the elastic modulus and hardness on ice with a nanoindentation test platform, as well as ice friction, and b) determine further changes for more extensive testing. Modifications in the test platform will provide an ability for more extensive testing to support the interpretation of large-scale experiments.

METHODS: The Hysitron TI 980 nanoindentation system (Bruker) with precision in the position and and force offers unique freedom for developing new tests. It is designed to determine the hardness, elastic modulus and creep properties from instrumented indentation using a small indenter. We determined the suitability of the standard test protocol for measuring mechanical properties of soft ice using a Berkovich indenter and proposed a suitable test protocol. A larger custom-designed 1 mm diameter probe was assessed and an approach developed for calibration of larger probes. Finally, initial mechanical tests were performed for conducting ice friction measurements from -5 °C to -20 °C with the larger 1 mm diameter probe. Data was collected in the nanoindentation test platform.

RESULTS/DISCUSSION: A list of modifications to the test procedure were implemented for testing ice. Firstly, the contact with the surface could not be registered on soft ice and so ice was frozen to colder temperatures and contct made on the harder surface for further testing. Another solution with contact on the contained wall holding the ice was not possible due to the small entry aperture of the cold cell. Secondly, calibration of the sample stage with the 1 mm sized probe that should remain uncontaminated was solved by visually identifying the position against a fine grid superimposed on the sample stage. Thirdly, the small aperture of the cold cell top-plate only allowed ice friction tests over a small lateral distance. A modified top plate for testing is being addressed. The testing of ice with larger probes containing special surfaces will be visually illustrated to show the range of mechanical tests possible.

Ice friction conducted over a range of temperatures showed higher friction at colder tempertures, lower friction at intermediate temperatures, and increased resistance at low temperatures due to the presence of a water film. The experimental design and friction results have direct implications for studying the friction of compacted snow. A procedure is being devised for determining the force for snow compaction, snow hardness and friction.

CONCLUSION: A new approach was developed for testing ice with the Bruker TI 980 nanoindentation test platform. The implications of this study show the next developments necessary to measure the compaction of snow, the mechanical properties of compacted snow and snow friction.

SKI WAX DISTRIBUTION AT THE SURFACE OF CROSS-COUNTRY SKIS

Pauline Lefebvre 1, Jean Herody [2], Frédéric Charlot[3], Nicolas Coulmy [2], Arnaud Mantoux 1, Nicolas Coulmy [2], Pascal Hagenmuller [4], Elisabeth Blanquet [1]*

[1]SIMaP, Grenoble Alpes University, Grenoble, France [2]French Ski Federation, Annecy [3]CMTC, Grenoble Alpes University, Grenoble, France [4]Centre d'Etudes de la Neige, CNRM, Météo-France, Grenoble, France

Keywords: Ski wax, SEM, EDX, mapping

INTRODUCTION: The International Ski and Snowboard federation (FIS) has banned fluorinated wax since winter 2023/2024 for health and environmental reasons [1]. Athletes must proceed to the inspection of their skis before each run to ensure no fluorine wax was used during the preparation. This control is currently done by infrared spectroscopy (FTIR) at three different points of the ski [2]. Very limited amount of wax can significantly improve the gliding performance [3]. One may thus wonder what the distribution of the wax onto the ski base is and what detection sensitivity should be attained for effective regulations?

METHODS: After cutting the ski into pieces, waxed ski bases were observed with a scanning electronic microscope (SEM) equipped with an energy dispersive X-ray (EDX) detector. When observed under an electron beam, a material emits X-rays with energies specific to the atoms it contains This technique allows the recognition of elemental constituents and their distribution mapping on the surface is possible on the SEM image. It requires that the wax contain different elements than the ski (carbon). Skis were prepared with a classical cross-country competition procedure. Different ski bases with different fluorinated waxes were analyzed. The effect of grinding with the absence or presence of a linear structure on the ski base was also investigated.

RESULTS/DISCUSSION: The presence of fluorine is very scattered. The distribution of wax is very variable with the ski base and the wax nature.
Ski base with graphite seems to retain less wax than no graphite containing with a presence of only small cluster of fluor.
PFA wax seems to be present only in small grooves parallel to the direction of skiing. This effect appears also on grinded ski even if it can be noticed an increase in the surface density in holes of the structure. It can be explained by the several brushing of the ski to remove the excess of wax.
Wax containing molybdenum either dispersed in PFA or paraffin are distributed in small cluster

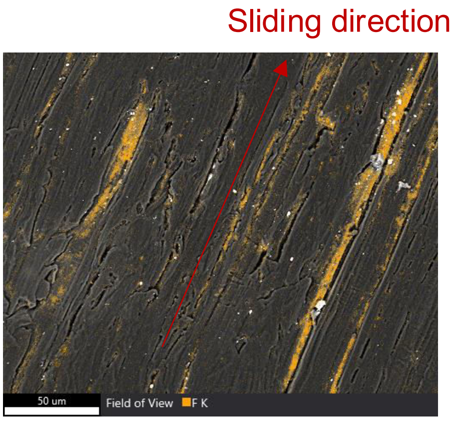


Figure: *SEM image with an EDX mapping of fluorine element in orange*

CONCLUSION: EDX is a suitable way to analyze wax qualitatively by detection of non-carbon elements such as fluorine and molybdenum. EDX-mapping is a powerful tool to measure the distribution of wax on the ski base. The distribution of wax can be very different depending on the ski base and the wax nature. However, it can be noticed the wax is mostly in grooves parallel to the sliding direction.

REFERENCES:

[1] Freberg, B. I. et al, 2010 Environ Sc & Techno
[2] Koehler I., 2024, Brucker, https://opticsblog.bruker.com/ftir-uncovers-fluorinated-ski-wax/
[3] Colbeck, S. C., 1994, J Sports Sc

A NEW ELECTRONIC RIFLE RANGE AND SHOOTING LABORATORY FOR BIATHLON TRAINING AND RESEARCH

Antti Leppävuori 1,, Keijo Ruotsalainen 1, Miika Köykkä [1,2], Vesa Linnamo [1,]*

[1] Vuokatti Sport Technology Unit, Faculty of Sport and Health Sciences, University of Jyväskylä, Finland [2] Finnish Institute of High Performance Sport KIHU, Finland

Keywords: Biathlon, testing, security

INTRODUCTION: Testing biathlon athletes in real shooting situations can be challenging. While laboratory environments offer numerous testing sites, ecologically valid ranges are scarce. In 2023, a biathlon shooting testing range with electronic biathlon targets was built in Vuokatti, providing the possibility to measure several shooting-related variables from both the athlete and the rifle, either inside a shooting cabin or outside in real-world conditions.

METHODS: The shooting cabin was built from a repurposed 8-meter sea container, while the target container was built by combining two 12-meter sea containers together, with one side opened towards the shooting range (Fig.1). All lead waste is collected. Suomen Biathlon Oy delivered the electronic targets with bullet traps and displays. Bullet protection was built exceptionally from 8 mm transparent carbonate plates, which can be adjusted individually for every track (Fig 2). The protective system was approved by the Finnish Police Government and is also suitable for small and residential areas. Noise tests were also conducted and approved by the local authorities. The range consists of six outdoor tracks with two indoor tracks. The shooting cabin is equipped with balance, force and aiming point movement measuring equipment, as well as cameras, all of which can be measured synchronously along with the target data and are collected to the Coachtech database for storage and analysis.

Figure 1. Shooting area with the containers

Figure 2. Bullet protection

RESULTS/DISCUSSION: Athletes have adopted the testing range well. The only change from a “normal” range is the compulsory use of ear protection. This is because the protection sheet bounces the sound backwards, opposite of what happens in a normal range. The electronic targets enable immediate feedback from the point of impact and trainers can focus on the athlete’s performance instead of tracking the shots through a scope. For research, the new facility opens possibilities to study the biathlete with different training situations and shooting positions. The electronic targets were in use for the first time on a biathlon track. During the summer, the manufacturer made modifications to the target system, and the next generation targets will be expected for further testing this Autumn.

CONCLUSION: The new shooting range enables new possibilities for training and research particularly in biathlon shooting.

CHOOSING SKI LENGTH: HOW MECHANICAL PROPERTIES EVOLVE ACROSS LENGTH AND WIDTH

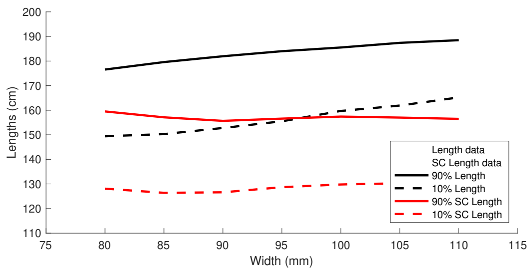
Alexis Lussier Desbiens[*1,2]

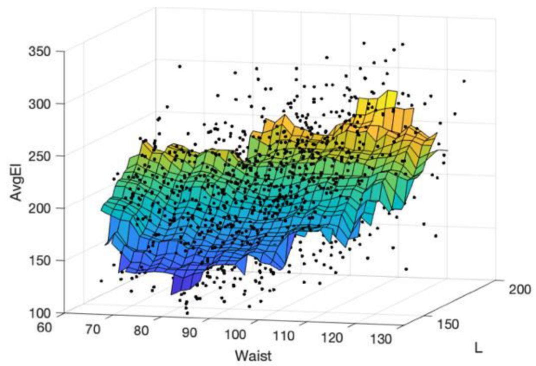
[1] Department of Mechanical Engineering, University of Sherbrooke, Sherbrooke, Canada
[2] Sooth Ski, Quebec, Canada

Keywords: alpine skis, mechanical properties, length, ski selection, normalization

INTRODUCTION: Ski length influences many on-snow characteristics, including stability, versatility and playfulness [1]. However, modern skis can vary from 145 to 195 cm, while a skier can easily use skis that vary by as much as 20 cm depending on the usage. As such, one of the most important questions customers are faced with is the selection of a suitable ski length. Existing selection rules typically use height to facilitate their application in shops, with various adjustments for terrain, skills, and skiing style. As the loads perceived by a ski depend on the skier's mass and acceleration, better sizing rules are envisioned. Furthermore, as the mechanical properties also influence the perception of length, understanding their scaling would allow for a better description of skis (e.g., *feel longer than expected*).

METHODS: A database of the mechanical properties of more than 5000 alpine skis is used (i.e., SoothSki [2]). Various length-related properties are investigated to find a *length selection factor* that would stay constant across all skis. Then, many mechanical properties (e.g., EI, GJ, mass, sidecut radius, stability) are normalized with different techniques to observe how they vary or stay constant across all lengths and widths. Percentile levels and spreads are extracted to better qualify these properties when compared to similar skis.





RESULTS/DISCUSSION: Results show that the 10 and 90 percentile levels of sidecut length are uniform for skis between 80 and 110 mm wide, while the lengths vary by about 15 cm (left figure). This suggests that a percentile ranking of skiers' applied loads could be used for ski length selection. Furthermore, many mechanical properties are scaling in interesting ways with length and waist width. For example, the average bending stiffness (EI) is scaling approximately linearly with length uniformly across all waist widths (right figure). The spread of bending stiffnesses observed between the 20 and 80 percentile levels is also constant at about 25% while the torsional stiffness (GJ) varies and can reach up to 80%.

CONCLUSION: A large dataset of mechanical properties was used to investigate constant length selection factors and the scaling of mechanical properties across all lengths and waist widths. One can imagine that skiers' applied loads could be mapped to these observed variations to select suitable lengths and mechanical property levels.

REFERENCES:
[1] Truong, J. et al., 2018. *Multidisciplinary Digital Publishing Institute Proceedings*
[2] www.soothski.com, accessed Oct. 13, 2024.

TECHNIQUE ANALYSIS OF A 50-KM CROSS-COUNTRY SKI MARATHON RACE USING HIGH-PRECISION KINEMATIC GNSS

Masaki Takeda [*1], *Naoto Miyamoto* [2], *Shunya Uda* [1], *Wako Kajiwara* [1], *Boye Welde* [3], *Thomas Stöggl* [4]

[1] Graduate School of Health and Sports Science, Doshisha University, Kyototanabe, Japan, [2] NICHe, Tohoku University, Sendai, Japan. [3] School of Sport Sciences, UiT The Arctic University of Norway, Tromsø, Norway. [4] Department of Sport and Exercise Science, University of Salzburg, Salzburg, Austria,

Keywords: Cross-country skiing, Sub-technique, Global navigation satellite system, Kinematic

INTRODUCTION: In ski marathon races, it has been revealed that elite skiers tend to use double poling more frequently than amateurs [1]. However, it remains unclear to what extent double poling and other sub-techniques are used throughout the course, spanning several tens of kilometers. Recently, high-precision kinematic GNSS devices enabled the classification of sub-techniques based on distinctive patterns of head movements [2]. This study aims to analyze the relationship between skiing speed and course slope for each sub-technique across a ski marathon race course based on the classification method.

METHODS: In a 50 km classic style race (Reistadlopet), a kinematic GNSS device (AT-H-02, AOBA Technologia LLC) was mounted on the back of a male elite skier to obtain 5 Hz centimeter-accurate positional data. Based on the classification method by Takeda et al. (2019) [2], sub-techniques (DP, KDP, DIA, downhill) used by the subject were identified from vertical movements of the upper thoracic spine in this study. In addition, the skiing velocity and course inclination were analyzed, and the time and distance usage ratios for each sub-technique were calculated.

RESULTS/DISCUSSION: The total race time was 2h31'41'', with the subject finishing 1st place. The average skiing speeds for each sub-technique were 6.49 m/s for DP, 4.15 m/s for KDP, 3.02 m/s for DIA, and 10.39 m/s for downhill. The average incline angles were 0.24° for DP, 3.36° for KDP, 6.73° for DIA, and -3.12° for downhill (Fig.1). The time usage ratios were 38.9% (59'1'') for DP, 12.9% (19'33'') for KDP, 31.5% (47'46'') for DIA, and 15.2% (23'1'') for downhill. The distance usage ratios were 43.9%(21.95km) for DP, 9.5%(4.75km) for KDP, 16.3%(8.15km) for DIA, and 29.1%(14.55km) for downhill. Since downhill was the 2nd highest distance usage ratio, it is evident that selecting skis and wax is crucial. The clear distribution pattern in Fig.1 indicates that the subject determined the sub-techniques based on skiing speed and incline angle, especially prioritized skiing speed rather than inclination angle.

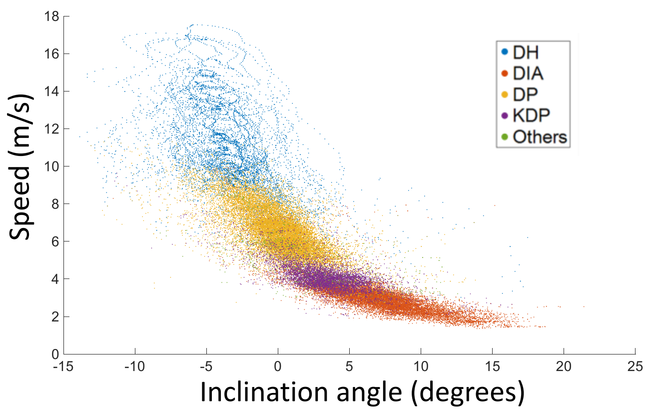


Fig.1 Distribution of inclination angle and speed for each sub-technique.

CONCLUSION: Throughout the race, DP proved to be the fastest technique and was the most frequently used in terms of both time and distance, followed by KDP and DIA. The findings of this study provide valuable insights into how elite athletes effectively utilize different techniques, which can contribute to improving future training programs and race strategies.

REFERENCES:

[1] Stöggl, T. et al, 2020 Frontiers in Physiology
[2] Takeda, M. et al, 2019 Sensors

UPPER LIMB MUSCLE ACTIVATION IN ELITE SKI-MOUNTAINEERS DURING SIMULATED SPRINTS ON SNOW

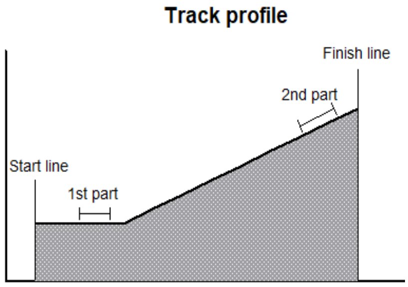
Beatrice Todesco [1,3], Bortolan Lorenzo [1, 2], Nina Verdel [4], Matej Majerič [4], Hans-Christer Holmberg[5], Matej Supej [4], Pellegrini Barbara [1, 2]

[1] CeRiSM Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy;
[2] Department of Engineering for Innovation Medicine, University of Verona, Verona, Italy;
[3] Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy; [4]Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia; [5] Department of Health Sciences, Luleå University of Technology, Luleå, Sweden.

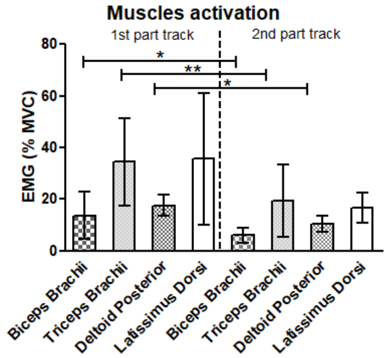
Keywords: electromyography, EMG, performance, SkiMo

INTRODUCTION: Ski mountaineering (SkiMo) is gaining prominence as it becomes part of the Milano-Cortina 2026 Winter Olympics, yet scientific literature on the discipline remains limited. Sprint competitions, as described by Fornasiero et al. [1], emphasize the importance of optimal performance during transitions and uphill sections, with training focusing on supramaximal efforts lasting 1.5–2.5 minutes. This study investigates upper body muscular activity during pole-pushing in flat and uphill sections, analyzing activation patterns and cycle time to better understand the biomechanical demands of sprint ski-mountaineering in elite athletes.

METHODS: Six elite SkiMo athletes completed maximal-effort tests on an outdoor uphill track simulating sprint competitions, replicating the typical duration and the positive elevation gain. EMG signal data were recorded for each subject, focusing on the biceps brachii long head (BB), triceps brachii lateral head (TB), posterior deltoid (PD), and latissimus dorsi (LT). Maximum voluntary contractions (MVC) were measured to compute relative muscle activation. Cycle time was calculated based on EMG data. RMS value for EMG was averaged over the cycle. Data were calculated over 10 conscutive cycles for each tract and statistical comparisons were performed to analyze differences in parameters between the flat section and the steep section of the course.



RESULTS/DISCUSSION: Results show a reduction in muscular activation among the 1st flat and the 2nd steep part of the track with significant differences in BB (14±8% vs. 6±2% MVC, P= 0.004), TB (34±16% vs. 19±13% MVC, P=0.001) and PD (17±4% vs. 10±3% MVC, P=0.01). No significant differences for LT were found. Results also show a significant difference in the cycle time, which increases among the 1st and the 2nd part of the track (0.78 ± 0.10s and 0.96 ± 0.16s respectively, P= 0.04).



CONCLUSION: This study highlights significant changes in muscle activation and cycle time when comparing the flat initial section to the steep final segment of the simulated SkiMo sprint course. However, it remains unclear whether these changes are driven by athlete fatigue or the increased slope incline. Future research should focus on analyzing an additional segment at the start of the steep slope to differentiate the effects of terrain from fatigue, providing insights into optimizing performance in critical uphill sections [1].

REFERENCES:

[1] Fornasiero, A. et al, 2023, Int J Sports Physiol Perform

A SUPERVISED MACHINE LEARNING APPROACH FOR TECHNIQUE IDENTIFICATION IN CROSS-COUNTRY SKIING USING USING POLE-EMBEDDED IMU SENSORS

*Gianluca Viscioni * [1,2], Matteo Meneghetti[3], Eldison Dimo[3], Emanuele Feola[3], Chiara Zoppirolli [1,3], Barbara Pellegrini [1,3], Andrea Calanca[3], Lorenzo Bortolan [1,3]*

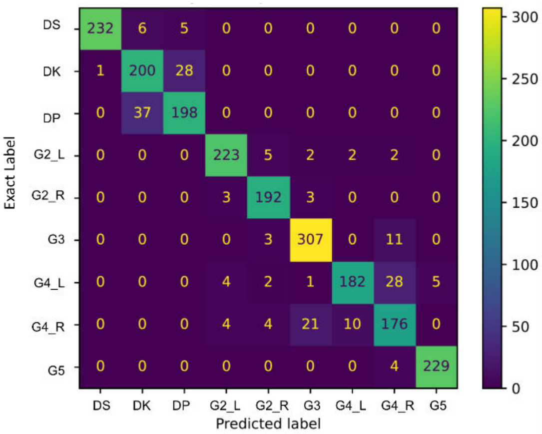
[1] CeRiSM (Research Center Sport Mountain and Health), University of Verona and Trento, Rovereto, Italy
[2] Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona, Italy
[3] Department of Engineering for Innovation Medicine, University of Verona, Verona, Italy.

Keywords: techniques classification, AI

INTRODUCTION: In both classical and skating styles, choosing the right sub-techniques is key to reducing energy use and enhancing performance. Tracking these choices during training and competition provides insights into race strategies and highlights areas for physical improvement. While previous studies have proposed automatic detection systems for sub-technique identification, none have utilized commercially available acquisition systems. This study aims to develop a machine learning algorithm capable of accurately identifying techniques and sub-techniques in XC skiing, leveraging existing technology.

METHODS: Raw data were acquired at a rate of 100 Hz from IMU sensors fitted into the handles of each of the two poles during cross-country skiing on a snow track, using both classical and skating techniques. Eight athletes participated in the data collection. A researcher labeled different parts of the data as specific sub-techniques, based on audio and video recordings taken during the skiing session. IMU data were used to estimate the inclination of the poles, with these estimates validated against 3D motion capture. The estimated angles were used to segment the recordings by leveraging peak angles of the poles. For each segmented window, a vector of 37 features was computed: 18 features per pole and an additional feature considering the phase delay between the poles. This vector was then used to train a multiclass Support Vector Machine (SVM) capable of classifying nine distinct skiing styles. To prevent overfitting, a stratified k-fold validation (k=5) approach was applied.

RESULTS/DISCUSSION: Data from all subjects were used to train the SVM algorithm, resulting in a subject-independent classifier. Classification performance was evaluated using standard metrics: accuracy (87%), precision (88%), recall (87%), and F1-score (87%). Additionally, a confusion matrix was employed to assess where errors in the classification model were made. The confusion matrix highlights that most classification errors occur between "double poling" (DP) and "double poling with kick" (DK), as well as between "G4_Rigth" with "G4_Left" (G4_L).



CONCLUSION: This method, using only data from sensors inside the poles, is the first known to be capable of automatically classifying skiers' techniques—both classical and skating—and also differentiating 'strong' and 'weak' side movements in skating.

REFERENCES:

[1] Pousibet-Garrido, A.; *Sensors* **2024**, *24*, 6422
[2] Jang, J.;*Sensors* **2018**, *18*, 3819.

DIAGNOSTICS OF STRENGTH ABILITIES OF PARALYMPIC ATHLETES

Kamil Povrazník,

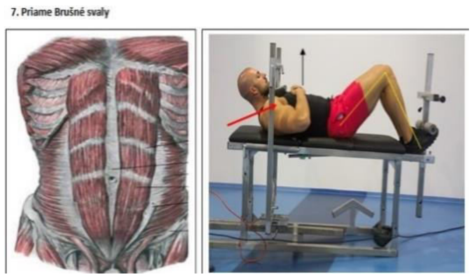
DCSP Diagnostic Center of Sport Performance, Slovakia, Poprad ,2024

Keywords: paralympic athletes, strength diagnostics

INTRODUCTION: Complex condition diagnosis of athletes is very important for maintaining the health of athletes primarily and secondarily for maintaining and increasing their sports performance. In our contribution, we want to demonstrate the methodology of a complete fitness diagnosis of the strength abilities of the paralympic athletes in alpine skiing. The results are important for planning their individual fitness training in eliminating strength imbalances.

METHODS: To determine strength capabilities, we used the isometric method of digital strength measurement with a strain gauge (Mobile PowerTest System) of rectus abdominis muscles, spinal extensors, quadriceps and hamstrings. We compared the results with athletes without a physical handicap.

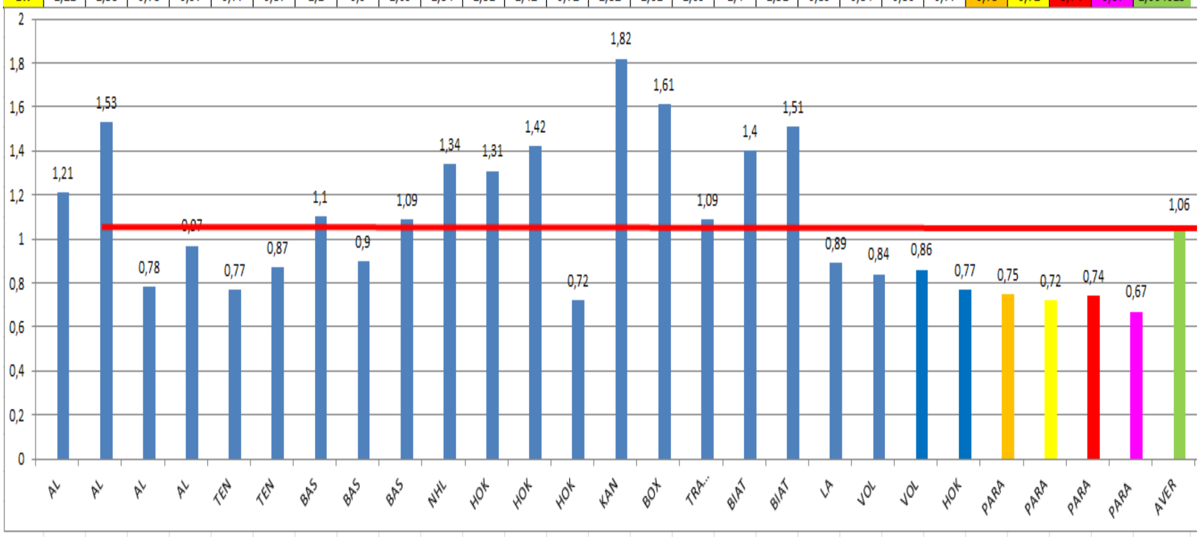
RESULTS/DISCUSSION: The results showed individual deviations of paralympic athletes in absolute strength, strength coefficient and strength imbalance. Compared to athletes without handicap, their rectus abdominis muscle strength was below average, spinal extensor strength above average, strength imbalance below average. Quadriceps strength



Diagnosis of rectus abdominis muscles

Comparison of strength coefficients in different sports.

DISC	AL	AL	AL	AL	TEN	TEN	BAS	BAS	BAS	NHL	HOK	HOK	HOK	KAN	BOX	TRAVA	BIAT	BIAT	LA	VOL	VOL	HOK	PARA	PARA	PARA	PARA	AVER
KAT	U21F	U21F	ALL	DH	MEN	ALL	MEN	FEM	FEM	MEN	ŠTM	ŠTM	INDI	MEN	MEN	ALL	MEN	FEM	Ban	MEN I.	MEN II.	Slovan	PLA	ALL	AL	LA	ALL
BR	1,21	1,53	0,78	0,97	0,77	0,87	1,1	0,9	1,09	1,34	1,31	1,42	0,72	1,82	1,61	1,09	1,4	1,51	0,89	0,84	0,86	0,77	0,75	0,72	0,74	0,67	1,064615



CONCLUSION: Exact, complex condition diagnosis of Paralympic athletes is important especially for maintaining their health, individual fitness training and increasing sports performance.

REFERENCES:

Jorg Sporri, et all, 2016, How to Prevent Injuries in Alpine Ski Racing: What Do We Know and Where Do We Go from Here?

SEX DIFFERENCES IN ELITE SKI MOUNTAINEERING AEROBIC PERFORMANCE

Forrest Schorderet, Justin Mottet, Aurélien Lathion, Antoine Raberin, Nicolas Bourdillon, Grégoire P. Millet

Institute of Sport Sciences, University of Lausanne, Lausanne, Switzerland.

Keywords: female athletes, ski mountaineers, maximal oxygen uptake, ventilatory threshold,

INTRODUCTION: Ski mountaineering (SkiMo) will be an Olympic sport (i.e., sprint and mixed relay events) at the upcoming 2026 Winter Olympic games. Despite its rising prominence, there is surprisingly a lack of research on SkiMo compared to the other winter sports [1]. SkiMo sprint is extremely demanding, uphill exercise time being ~80-93% of total race time in elite athletes [2]. Consequently, both body composition and maximal oxygen consumption ($\dot{V}O_{2max}$) are paramount [3]. Previous studies have reported the physiological characteristics of elite male SkiMo athletes but limited data exist on female athletes [3,4]. To address this gap, the present study aimed to analyze sex differences in physiological parameters of elite SkiMo athletes. The hypothesis was that sex differences in vertical velocity (vV) would exceed the differences in $\dot{V}O_2$ at submaximal and maximal aerobic intensities.

METHODS: Twenty elite ski mountaineers (6 women, 14 men), member of the Swiss national team, aged 20–32 years, participated in this study. They all had competed at the World Cup level, with many achieving top-3 ranking. Athletes performed a submaximal exercise followed by a graded exercise to exhaustion (treadmill with 25% slope; initial speed = 3.5 km/h for women and 4 km/h for men; increment = 0.3 km/h each 1-min stage; with poles) with breath-by-breath cardiorespiratory measurements continuously collected (Quark CPET, Cosmed, Rome, Italy). The first and second ventilatory thresholds (VT1, VT2), as well as at maximal intensity (MAX), were determined by visual inspection from three examiners.

RESULTS/DISCUSSION: Elite female SkiMo athletes had a $\dot{V}O_2$ value 13.6% lower at MAX (64.0 ± 3.8 vs. 72.8 ± 5.5 ml/kg/min; $p = 0.002$) and 15.5% lower at VT_2 (54.8 ± 2.8 vs. 62.2 ± 5.8 ml/kg/min; $p = 0.009$) than their male counterparts. Interestingly, the sex-differences in vV at both MAX (1825 ± 113 vs. 2125 ± 156 m/h; $p < 0.001$; 16.4%). and VT_2 (1412 ± 56 vs. 1696 ± 151 m/h; $p < 0.001$; 20.1%) intensities were consistently larger than the differences in $\dot{V}O_2$, which supports the main hypothesis. Further investigation on the underlying mechanisms is requested but the following factors may contribute to the larger sex-differences in uphill velocity than in the well-known aerobic power [5]: Firstly, women generally have a higher body fat percentage, a finding corroborated in our study (15.2 ± 1.0% vs. 6.6 ± 0.6%; p = 0.004). Secondly, women have a higher proportion of slow-twitch oxidative fibers and fewer fast-twitch fibers, which may disadvantage them in uphill locomotion due to its reliance on concentric contractions and force production. Additionally, men also generate more power output, likely due to greater upper body muscle mass [6]. Finally, the pulmonary system shows significant sex differences during hypoxia, with women experiencing greater hypoxemia and increased work of breathing compared to men [7].

CONCLUSION: The sex-differences in uphill velocities (16.4-20.1%) were larger than the differences in $\dot{V}O_2$ (13.6-15.5%) or than the commonly reported 10-12% difference in road runners [8]. Overall, the present findings are in line with the 16-17% difference in performance times reported in three major mountain ultra-marathons [9]. The performance gaps between men and women appear to be larger in uphill sports.

REFERENCES:

[1] Bortolan,L et al, 2021 Front Physiol
[2] Fornasiero, A et al, 2023 J Human Kinetics
[3] Fornasiero, A et al, 2018 Sport Sci Health
[4] Lasshofer M, 2021. J Sports Sci Med
[5] Sandbakk, O, 2018 Int J Sports Physiol Perform
[6] Hegge, AM et al, 2016. Eur. J. Appl. Physiol.
[7] Raberin, A, et al, 2024 Sports Med
[8] Hunter, S.K, Senefeld, J.W, 2024 J Physiol
[9] Millet, GP, Malatesta, D, 2022 J Appl Physiol

THE EFFECT OF COURSE DESIGN ON THE NUMBER OF RANK SHIFTS IN SKICROSS WORLD CUP FOR WOMEN AND MEN

*Linda Tomelleri *[1], Ivar Hereide Mannsåker [1], Thibault Lachaize [2], Willemijn Wortelboer [3], Jeremy Pfyffer [4], Michael Lasshofer [5] Matthias Gilgien [1,6]*

[1] Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway [2] UFR Science et Montagne, Université Savoie Mont Blanc, Chambéry, France [3] Human Movement Technology, The Hague University of Applied Sciences, Den Haag, Netherlands [4] Department of Health Sciences and Technology, Federal Insitute of Technology ETH, Zurich, Switzerland [5] Athlete Health Unit, International Ski and Snowboard Federation FIS, Oberhofen, Switzerland [6] Center of Alpine Sports Biomechanics, Engadin Health and Innovation Foundation, Samedan, Switzerland

Keywords: biomechanics, performance, competition, freeski

INTRODUCTION: In World Cup Skicross, athletes compete in heats of four to advance through a cup system to the big final, where the winner of the competition is crowned. The courses include terrain obstacles such as jumps, rollers, dragon backs, and turns of various types. The obstacles are built to challenge the technical, tactical, and physical abilities of the athletes, and to separate them from each other and to create a competition that is exciting to ski and exciting to watch. For the sport to be attractive to the athletes and spectators, the races should allow athletes to fight for their position throughout the course and change their ranking several times on their way from start to finish [1]. Therefore, course designers need to understand and build courses that provoke and allow athletes to frequently overtake each other. To gain quantitative knowledge on how course characteristics create opportunities for rank shifts between athletes within a heat, this study examined the relationship between course characteristics and rank shifts in Men and Women World Cup Skicross.

METHODS: In the 2023/24 season, five World Cup races (Innichen, Alleghe, St. Moritz, Reiteralm, Veysonnaz) for women and men were analysed for the issue of rank shift. The geometric characteristics of the World Cup courses were captured using differential GNSS to create digital terrain models, from which the type and location of the obstacles were derived. Human raters used TV footage of all final heats for men (from 8th finals) and women (from 4th finals) to assess the location and time of rank shifts between athletes. A rank shift was counted when the skis of one or more athletes skiing in the same position moved away from each other so that they no longer overlapped. Human raters also identified events where athletes were out of balance. The out of balance events were used in the analysis as a measure of how challenging an obstacle was for the athletes. Athletes from one nation carried a standalone GNSS to measure position and time and to calculate continuous speed. Chi-square tests were used to compare the number of rank shifts between the five events, between women and men, and between course sections (courses were divided into 4-5 sections based on the logic of course design by the International Ski and Snowboard Federation (FIS) race directors).

RESULTS/DISCUSSION: The number of rank shifts differed between women and men for sections as well as whole races. Men had significantly more rank shifts than women. The number of rank shifts also differed between races for both women and men. Most rank shifts occurred on the start straight section for both women and men. Speed and out of balance events affected rank shifts for both sexes.

CONCLUSION: Courses need to be designed to produce sufficient rank shifts, particularly for women, to be attractive for athletes and spectators. This study found that course difficulty and speed are the key aspects to achieving a higher number of rank shifts.

REFERENCES:

[1] Brusveen, H. 2020. Norwegian School of Sport Sciences

ACUTE FATIGUE EFFECTS OF TWO DIFFERENT PLYOMETRIC JUMPS ON LANDING GROUND REACTION FORCE, TIME TO STABILIZATION, JUMP HEIGHT AND INTER-LIMB FUNCTIONAL ASYMMETRY

*Nicola Trotta[1] *, Italo Sannicandro[1]*

[1] Department of Clinical and Experimental Medicine, University of Foggia, Foggia, Italy

Keywords: plyometric training, fatigue, cmj, inter-limb asymmetry

INTRODUCTION: Fatigue is a phenomenon associated with decreases in physical performances and increases in injury occurrence [1]. Fatigue is associated with changes in neuromuscular control strategies during sport-specific tasks [2]. No-contact injuries often occur during dynamic actions such as landing or cutting movements. Inter-limb asymmetries are suggested as one possible cause for those injuries based on findings indicating that asymmetries between limbs are associated with a higher injury risk [3]. The study aims to verify the effects of neuromuscular fatigue on some jump parameters and inter-limb asymmetry after two different plyometric exercises.

METHODS: Sixteen recreational skiers (age: 26,7±2,4 years; height: 177,8±4,2 cm; weight: 75,9±2,9 kg) took part in this study. They performed jumping tests (Countermovement Jump, CMJ, on two force plates 1000 Hz, Globus Italia; hop test, HT, on the ground) before and after 6x15 CMJ with maximum effort (rec 1min inter-set). Subsequently (after 48 h), all athletes completed 6x15 Tuck Jump (TJ). Force platforms with associated software measured the Ground Reaction Force (GRF) at landing, the time to stabilization (TTS) and the jump height (JH); through the HTs, jump length and inter-limb functional asymmetry were measured. The asymmetry calculation was carried out using the formula: (NDL / DL) x 100 [4]. A non-parametric Wilcoxon-Mann-Whitney test was used to calculate the statistical significance established for $p<0.05$.

RESULTS/DISCUSSION: Table 1 and 2 shows mean values and standard deviation for GRF, JH, HT and TTS. All measured parameters were significantly ($p<0.001$) affected by plyometric loading.

	Landing GRF (N)		% Asymmetry	TTS (sec)	
	Left	Right		left	right
Pre plyometric load	2132,56±126,50	2104,31±115,54	4,48±2,42	1,93±0,11	1,95±0,10
Post 6x15 CMJ	2887±241,03 ***	3060,50±367,32 ***	13,36±5,01 ***	3,16±0,49 ***	3,18±0,52 ***
Post 6x15 TJ	2464,44±193,45***	2529,56±257,85***	9,54±3,87***	2,98±0,46 ***	3,02±0,43***

Table 1. Results.***p<0.001 significantly different from pre-plyometric load

	JH (cm)	HT (cm)		% Asymmetry
		left	right	
Pre plyometric load	37,33±1,01	193,19±6,52	193,63±5,67	3,81±2,22
Post 6x15 CMJ	26,29±2,72***	153,81±12,51***	158,50±14,46***	14,24±3***
Post 6x15 TJ	31,55±1,94***	168,94±8,97***	162,19±12,37***	10,18±5,16***

Table 2. Results. ***p<0.001 significantly different from pre-plyometric load

The results of this study showed that inter-limb asymmetry increased because of fatigue-induced plyometric training. Hence, monitoring vertical and horizontal jumping test is recommended to detect significant changes in physical performance of recreational skiers.

CONCLUSION: Plyometric jumping exercises appear to cause acute fatigue that affects both the quantitative/qualitative parameters of the vertical jump and the asymmetry values that reach the cut-off for the lower limb no-contact injury risk [5]. In training sessions, it is necessary to understand how to schedule the different exercises to reduce the injury risk and ensure movement control.

REFERENCES:

[1] Bestwick-Stevenson, T. et al, 2022 Int J Sports Med
[2] Fort-Vanmeerhaeghe, A. et al, 2023 Journal of Human Kinetics
[3] Heil, J. et al, 2020 Sports Medicine
[4] Bishop, C. et al, 2016 Strength and Conditioning Journal
[5] Bishop, C. et al, 2018 Strength and Conditioning Journal

PHYSIOLOGICAL RESPONSES TO HEAT STRESS DURING SUMMER JUMP TRAINING IN SNOWBOARDERS

Risa Iwata[1], Yusuke Yamamoto[2], Mariko Nakamura[1], Eri Takai[3], Yui Takahashi[3], Hiroki Ozaki[1]

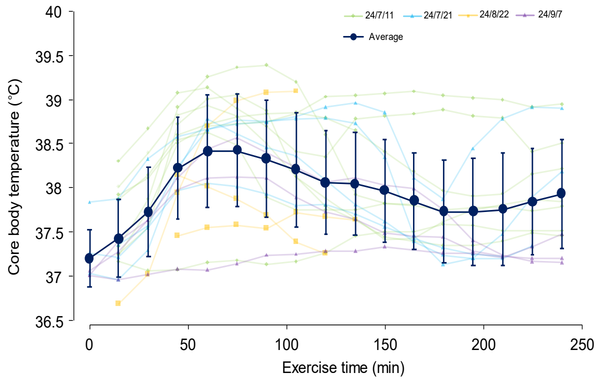
[1]Department of Sport Science and Research, Japan Institute of Sport Sciences, Kita-ku, Tokyo
[2]Digital Promotion Office, Japan Sport Council, Kita-ku, Tokyo
[3]Department of Sports Medicine, Japan Institute of Sport Sciences, Kita-ku, Tokyo

Keywords: Core body temperature, Heart rate, Slopestyle, Big air

INTRODUCTION: Summer jump training in snowboarding in Japan takes place in a hot environment. Additionally, athletes wear long sleeves, long pants, boots, gloves, and helmets during summer training, which results in higher heat stress compared to other sports. Exercise in hot environments leads to an excessive increase in core body temperature, which can impair muscle strength, skill performance, and decision-making speed [1]. These factors pose a major problem in summer training to improve jumping skills. Therefore, this study aims to evaluate the physiological responses during summer jump training and provide insights into appropriate load management and cooling strategies.

METHODS: The participants were 16 snowboard athletes from Japan in Slopestyle and Big Air. Measurements were taken during summer training at three sites in Japan (T_{amb}, 29.6 ± 3.8°C; %rh, 66.7 ± 10.1%; and WBGT, 26.5 ± 2.0°C). Physiological measurements during training included heart rate (HR), core body temperature (Tcore), skin temperature, and body weight. From skin temperature, estimated muscle temperature was calculated, and dehydration rate was calculated from body weight.

RESULTS: The mean maximum Tcore during exercise increased to 38.61±0.53°C, with a mean maximum HR of 158 ±14 bpm. There was a significant positive correlation between maximum HR and Tcore ($r = 0.600$, $p = 0.008$), whereas there was no correlation between maximal Tcore and environmental temperature. The mean HR during training was 115±14 bpm, and the mean Tcore was 38.01 ± 0.46°C. Maximum estimated muscle temperature increased to 37.0 ± 0.9°C, with a mean of 34.71±1.53°C. The mean dehydration rate was 0.60 ± 0.87%.



DISCUSSION/CONCLUSION: Core body temperature exceeded 38.5°C, a threshold at which performance is decline [2]. Although the increase in Tcore depends on the individual, cooling strategies could be effective in maintaining performance. While there was a significant correlation between Tcore and HR, there was no association between environmental Tcore and temperature. This indicated that the increase in Tcore in snowboard jump training was related to exercise intensity rather than environmental temperature.

REFERENCES:

[1] Schmit, C. et al. Sport. Med. 2017.
[2] Nybo, L. J Appl. Physiol. 2008.

THE PROCESS OF PSYCHOLOGICAL TRAINING FOR THE ALPINE SKIING INSTRUCTORS - THE ROLE OF THE COACH DEVELOPER

Marcin Krawczyński[1,2], Piotr Aschenbrenner[1], Tomasz Grzywacz[1,3] , Wojciech Woźnica[4]

[1]Faculty of Physical Culture, Gdańsk University of Physical Education and Sport, Gdańsk, Poland, [2]Ateneum University, Gdańsk, Poland, [3]Polish Ski Association, [4]Wrocław University of Health and Sport Science, Wrocław, Poland

Keywords: sport psychology, coach developer, alpine ski

In the Polish system of training for Alpine skiing instructors the responsible person for teaching is a trainer/lecturer. Previously trainer/lecturer was oriented on improving their hard skills and at the same time undermining soft skills. One of the crucial components for the Alpine skiing instructors while their training is fitting them up with psychological competencies – soft skills (Erickson, Camire & Gilbert, 2021; Gilbert, 2017). The key challenge of modern education is to provide people with the tools to be flexible and open to constant changes and to prepare themselves to be creative and critical towards reality. In the presentation, the author describes the process of learning with the Theory of Experiential Learning - the so-called D.A. Kolb Cycle (Kolbe & Kolbe, 2022). It also highlights the need to transfer the teaching (academic) style to the workshop style in teaching skiing. It presents the main differences between the instructor (trainer) and the educator of other instructors (trainers) – coach developer. Instructor educators (coach developers) have the skills to develop, support and challenge other instructors (trainers) for long-term learning and development (Gould & Mallett, 2021). Undoubtedly, the educator's activities should be an integral part of the training system of the training staff of each sports organization and result from the adopted development strategy of the organization. The presentation illustrates the issues discussed with the selected content of the Polish coach developer training for the Association of Ski Instructors and Trainers of Polish Ski Association (SITN PZN) involving skills in line with the recommendation of the International Sport Coaching Framework (ISCF) (2013) coaching competence and coach development based on six primary tasks undertaken by sport coaches: 1) Setting vision and strategy; 2) Shaping the environment; 3) Building relationships; 4) Conducting practices and preparing for competitions; 5) Reading and reacting to the field; 6) Learning and reflecting.

REFERENCES:

[1] Erickson, K., Camire, M., & Gilbert, J.N. (2021). Psychological and social development of athletes. In D. Gould, & C. Mallett (Eds.), *Sport coaches' handbook* (pp. 133–153). International Council for Coaching Excellence & Human Kinetics.
[2] Gilbert, W. (2017). *Coaching better every season*. Human Kinetics.
[3] Gould, D., & Mallett, C. (2021). The coaching role. In D. Gould, & C. Mallett (Eds.), *Sport coaches' handbook* (pp. 1–13). International Council for Coaching Excellence & Human Kinetics.
[4] International Council for Coaching Excellence, Association of Summer Olympic International Federations, & Leeds Beckett University (2013). *International sport coaching framework (Version 1.2)*. Human Kinetics.
[5] Kolb, A.Y., & Kolb, D.A. (2022). *Uczenie na podstawie doświadczania. Podręcznik dla edukatorów, trenerów, coachów*. Poznań: Dialog&Zmysły.

ABOUT THE CONCEPT AND EFFECTS OF ALPINE SKIING AS A SPORT THERAPY PROJECT WITH CHILDHOOD CANCER SURVIVORS

Nicolas Kurpiers[1]

[1] Department of Sport Science, University of Hildesheim, Hildesheim, Germany

Keywords: Cancer, Children, Rehabilitation, Sport, Skiing

INTRODUCTION: This contribution introduces a specific family-oriented wintersport rehabilitation project for pediatric cancer survivors and their families. Its underlying concept [1] is embedded into a broader comprehension of health, coping, resilience and general wellbeing. The results of several studies with this specific clientele are summarized [2-5].

METHODS: For the therapy journey 50 persons are living in a self-service hut in the alps once a year for one week. This group consists of ten patients (5-18 years) and their families and a team of 13 persons for care, teaching and medical monitoring. The program comprises two guided skiing sessions per day besides various other leisure activities. We conducted studies with one to 26 participants over several years ranging from immunological parameters measured in the blood over motor interaction such as balance ability measured via a mobile balance board. The exhaustion intensity of the skiing activity was assessed via heart rate measurements and a questionnaire and the psychological wellbeing and functionality was thoroughly investigated using a clinical survey tool.

RESULTS/DISCUSSION: The patients showed a significant increase in balance ability after one week of alpine skiing (N=18 IG vs. N=8 CG) while the exhaustion intensity was rated as moderate. In this regard the subjective perception was in accordance with the concurrently assessed heart rate of the children (N=17 CG, N=8 CG). The immunological status has positively changed in one participant after the intervention and the general wellbeing and psychological functionality of the children (N=8) has been rated by their parents in terms of e.g. social behavior, hyperactivity, emotional problems beside others. The surveyed items showed particularly positive effects for an increased perceived health-related life quality.

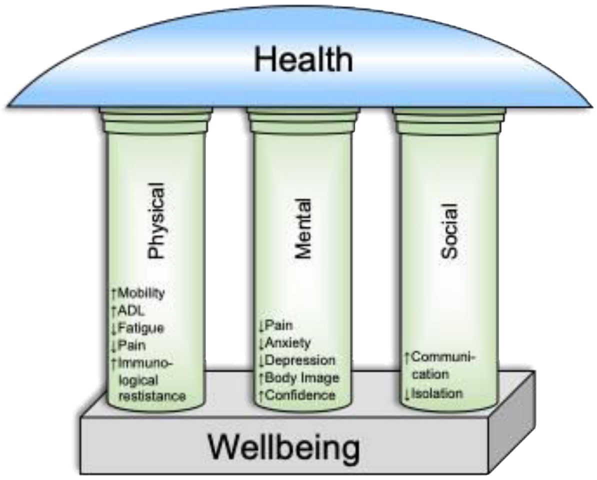


Fig.: 3 pillars of health understanding

CONCLUSION: In conclusion this rehabilitation journey seems promising for several healing effects. It is an interdisciplinary scientific project regarding sports medicine, psychology, psychotherapy, human genetics, sports science, and also a valuable follow-up-care-project.

REFERENCES:

[1] Kurpiers, N., 2024 *B&G* 40 :2 5 –31.
[2] Kurpiers, N., et al., 2018 *Int. J. of Sports and Exercise Medicine*, 4, 105.
[3] Kurpiers, N., et al., 2024 *J. of Clinical Cases & Reports*, 4, 203-208.
[4] Kurpiers, N. et al., 2019 *Int. J. of Sport and Exercise Medicine*, 135, 5.
[5] Kurpiers, N. et al. 2023 *J. of Physical Medicine Rehabilitation Studies & Reports*, 5, 5.

BETTER ESTIMATION OF SKILLS LEVEL IN RECREATIONAL SKIING: DEVELOPMENT AND VALIDATION OF A PRACTICAL MULTIDIMENSIONAL INSTRUMENT

*Floriana Luppino[1] *, Margien den Hollander-Gijsman[2], Friedo Dekker[3], Kornelis Bartlema[4], Merel van Diepen[3].*

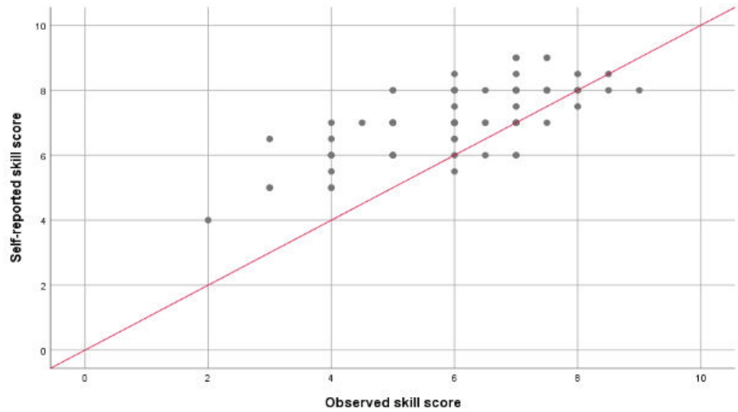
[1] Eurocross Assistance, Leiden, the Netherlands [2] Department of Information Technology and Digital Innovation, Leiden University Medical Centre, the Netherlands [3] Department of Clinical Epidemiology, Leiden University Medical Centre, the Netherlands [4] Department of Traumatology, Leiden University Medical Centre, the Netherlands

Keywords: prediction model, skills level assessment, validation

INTRODUCTION: Skiing and snowboarding are both popular recreational alpine sports, with substantial injury risk of variable severity. Although skills level has repeatedly been associated with injury risk, a validated measure to accurately estimate the actual skills level without objective assessment is missing. A validated measure is essential to better examine the association between skills level and injury risk. We therefore aimed to develop a practical validated instrument, to better estimate the actual skills level of recreational skiers, according to the golden standard criteria of the Dutch Skiing Federation (DSF), and covering five skill domains.

METHODS: A sample of Dutch recreational skiers (n=84) was asked to fill in a questionnaire reflecting seven, a priori chosen predictors by expert opinion, to ski downhill and to be objectively evaluated by expert assessors. The instrument was developed to have a multidimensional character, and was validated according to the TRIPOD guidelines.

RESULTS/DISCUSSION: The sample reported an overall incorrect estimation of their skills. The instrument showed good calibration, and underwent multiple validation methods. The estimated skills score showed to be closer to the observed scores, than self-reportage.



<u>Predicted skills level</u>

−0.850 + (self−reported skill score ∗ 0.969)
+ (gender ∗ −0.510)
+ (skiing days per year ∗ 0.037)
+ (avoidance of fog ∗ −0.121)
+ (avoidance of certain weather conditions ∗ −0.611)
+ (ski boot rental ∗ 0.491)
+ (physical preparation ∗ 0.779).

CONCLUSION: Our study provides a practical, multidimensional and validated prediction instrument of the actual skills level among recreational skiers. It's outcomes are more accurate than self-estimation. This model is a first step toward a new skills level assessment approach, and directly applicable in studies investigating the association between the skills level and ski injury.

REFERENCES

[1] Sulheim, S. et al, 2011 Br J Sports Med.
[2] Goulet, C. et al, 2010 J Sci Med Sport.

FROM SKIMOUNTAINEERING TO UNRAVELING DOMS MECHANISMS

Lorenzo Visconti, Matthias Eggermont, David Beckweé

RERE VuB Bruxelles

Keywords: DOMS, Myalgia, Ski Mountaineering

Introduction: We have demonstrated that various treatment modalities yield similar effects in reducing DOMS (Delayed Onset Muscle Soreness) in ski mountaineering athletes (Visconti et al., 2020). This underscores the need to clarify the mechanisms of DOMS as described in the literature, given its impact on performance. A specific approach to treatment may have significant implications.

Methods:A review was conducted using the PubMed and Scopus databases. The study is registered with Prospero (2024 CRD42024421684). We included only observational studies (longitudinal, cross-sectional) involving adult humans. Language restrictions applied to studies published in English, French, or Italian. Our PICO research focused on DOMS mechanisms, encompassing factors such as inflammation, mechanical damage to skeletal muscle, myofibrillar integrity, sarcomere breakdown, protein degradation, autophagy, inactive muscle fibers, lumbar disorders, tissue perfusion, oxidative stress/reactive oxygen species (ROS), and satellite cell activation via intrinsic or extrinsic signals. Two independent researchers conducted the study selection using Ryyann, with a third researcher resolving any conflicts. Risk of bias quality assessment was performed using the NIH tool for observational cohort and cross-sectional studies.

Results: Out of the articles analyzed, 45 met our criteria. Notable findings include:

- DOMS onset may relate to desmin remodeling (Yu, 2014).
- Vasodilating agents like calcitonin appear significant (Jonhagen, 2006).
- Type 2 muscle fibers are more susceptible to DOMS than type 1 fibers (Kellermann, 2017).

Discussion/Conclusion DOMS is a physiological phenomenon under active investigation. This systematic review elucidates the mechanisms behind DOMS onset, facilitating the development of more specific treatment strategies, which currently present considerable heterogeneity in the literature. Exploring the potential role of Blood Flow Restriction (BFR) training in preventing DOMS in the ski mountaineering population would be particularly intriguing, considering the vasodilation-related factors influencing its onset.

References

[1] Visconti, L., Forni, C., Coser, R., Trucco, M., Magnano, E., & Capra, G. (2020). Comparison of the effectiveness of manual massage, long-wave diathermy, and sham long-wave diathermy for the management of delayed-onset muscle soreness: a randomized controlled trial. *Archives of Physiotherapy*, 10, 1. https://doi.org/10.1186/s40945-019-0073-4

[2] Jonhagen, S., Ackermann, P., Saartok, T., & Renstrom, P. A. (2006). Calcitonin gene-related peptide and neuropeptide Y in skeletal muscle after eccentric exercise: a microdialysis study. *British Journal of Sports Medicine*, 40(3), 264–267. https://doi.org/10.1136/bjsm.2005.022731

[3] Kellermann, M., Heiss, R., Swoboda, B., Gelse, K., Freiwald, J., Grim, C., Nagel, A., Uder, M., Wildner, D., & Hotfiel, T. (2017). Intramuscular perfusion response in delayed onset muscle soreness (DOMS): A quantitative analysis with contrast-enhanced ultrasound (CEUS). *International Journal of Sports Medicine*, 38(11), 833–841. https://doi.org/10.1055/s-0043-112501

[4] Yu, J. G., Liu, J. X., Carlsson, L., Thornell, L. E., & Stål, P. S. (2013). Re-evaluation of sarcolemma injury and muscle swelling in human skeletal muscles after eccentric exercise. *PloS One*, 8(4), e62056. https://doi.org/10.1371/journal.pone.0062056

AVOIDING MODE-MONOTONY: HOW WORLD-CLASS CROSS-COUNTRY SKIERS USE EXERCISE MODE VARIATIONS TO MANAGE DAILY LOAD

Jacob Walther[1,2], Jan Kocbach[1] and Øyvind Sandbakk[1,3]*

[1]Centre for Elite Sport Research, Department of Neuromedicine and Movement Science, Norwegian University of Science and Technology, Trondheim, Norway
[2]Institute of Human Movement Science and Health, Department of Sports Medicine and Exercise Therapy, Chemnitz University of Technology
[3]School of Sport Science, UiT The Artic University of Norway, Tromsø, Norway

Keywords: training characteristics, exercise modes, endurance sports, micro-periodization

INTRODUCTION: Cross-country (XC) skiers usually compete and train in two different styles (skating and classical) with several sub-techniques included. Additionally, XC-skiers also apply cross training by including unspecific modes like running and cycling into their training. While a wealth of research has investigated annual training characteristics in world-class skiers, little is known about the load management during shorter training periods and especially the role of exercise modes in training load management is sparsely investigated. Therefore, the purpose of this study was to investigate the mode-monotony and day-by day application of different exercise modes by world-class cross-country skiers in the context of volume and intensity of endurance training.

METHODS: Session-by-session self-reported endurance training of 17 (7 female) world-class cross-country skiers (28.4±2.7y) of an entire season (365 days, separated for general preparation and competition phase (GP and CP) in which they attained world-class performance (medal at OWG, WSC or repeatedly on the podium in WC) was retrospectively researched. Session analyses included duration, intensity and modalities (skating and classical style, running, cycling, kayaking, and others) and differentiations for specific on-snow skiing and semi-specific roller skiing for additional analyses. A session was defined according to an applied mode if containing at least 10 minutes of that mode with multiple modes per session possible. Intensive sessions were handled equally with a threshold of 10 minutes of the interval part to be accounted in that mode. Mode-monotony was calculated as the proportion of the most applied mode (i.e., time spent) in a given period.

RESULTS/DISCUSSION: Mean weekly mode-monotony was 41.2±5.7% and 47.2±4.8% during GP and CP respectively, while the corresponding weekly scores were 48.3±4.3% and 55.0±5.2%. Distribution of time gaps between session of the same mode for 0 (same day), 1, 2, 3, 4, 5+ days was 5, 43, 25, 12, 6, 10% during GP while the corresponding values for CP were 5, 47, 21, 12, 11, 15%. During GP, 21% of the intensive sessions were performed ≥14 days after the last intensive session with the same mode while the other sessions were evenly distributed across 0-13 days (all <10%). This was reversed during CP with 18±6% back-to-back intensive days with same mode (including races), while other time gaps were all ≤11%. The day before and after intensive sessions 47±8% and 40±12% of days contained same mode during GP while the corresponding values for CP were 60±7% and 46±7%.

CONCLUSION: The data provides new insights on the day-by-day application of different exercise modes by world-class cross-country skiers. The findings show high variations of modes with mode-monotony barely exceeding 50%. While skiers commonly apply the same mode with gaps of 1 to 2 days, intensive sessions with the same mode are separated by larger time intervals.

METABOLIC RESPONSES IN THE ANNUAL TRAINING CYCLE OF HIGHLY TRAINED CROSS-COUNTRY SKIERS

Evgeny Bojko[1], Alexandra Lyudinina[1], Olga Parshukova[1], Natalya Potolitsyna[1], Nina Varlamova[1].

[1] Institute of Physiology, Komi Science Center of Ural Branch of Russian Academy of Sciences, Russia,

Keywords: cross-country skiers, test "until exhaustion", aerobic performance, fatty acids, nitric oxide.

INTRODUCTION: Studies of biochemical markers, including essential nutrients, are of a great interest in the world of sport because of key roles these compounds and metabolites have in enhancing physical performance. The aim of this work was to estimate the biochemical markers of physical and aerobic performance (AP) of highly trained cross-country skiers.

METHODS: We examined cross-country skiers – members of regional and national teams (n=38, men, age 18–27 years) in an annual training cycle. We have developed an original procedure for complex testing of athletes. The procedure included a test of maximum physical performance (PP) (on a cycle ergometer, "until exhaustion") using the ergospirometric system ("Oxycon Pro", Germany), and a panel of biochemical tests, that gave the most information for evaluation of physical and aerobic performance in the dynamics of the test [1].

RESULTS: We propose that the exercise test "until exhaustion" combined with the assessment of the levels of stable nitric oxide metabolites in plasma can be considered a test for the early diagnosis of endothelial dysfunction in professional athletes [5]. Athletes of higher qualifications revealed additional adaptive mechanisms of metabolic regulation, which manifested themselves in the independence of serum lactate from V'O2 max under submaximal and maximum load. They also displayed an NO-dependent mechanism for regulation of lactate levels during aerobic exercise [4]. The participation of essential n-3 PUFAs in the nitrite–nitrate pathway of NO synthesis in highly trained skiers was demonstrated [3]. Literature data and our own results indicate a link between the AP and increased utilization of fatty acids as an energy supply in athletes. The plasma fatty acid profile in skiers was characterized by a decreased percentage of saturated fatty acids and n3-linolenic and docosahexaenoic acids. For the first time, we showed a significant role of medium-chain fatty acids during loads of submaximal and maximal intensity (both during tests and in competitive conditions) [2]. In the training period we observed an increased maximal fat oxidation (MFO) in athletes with higher qualification compared to the athletes with lower qualification. Adequate recommended dietary intakes of alpha-linolenic acid and its plasma level are associated with both MFO and high AP [1].

CONCLUSION: We found a novel mechanism of increased aerobic performance in highly trained athletes, and a number of biochemical and lipid markers that contribute to the increased aerobic performance.

REFERENCES:

1. Lyudinina, A.Yu., Bushmanova, E.A., Varlamova, N.G., Bojko, E.R. Dietary and plasma blood α-linolenic acid as modulators of fat oxidation and predictors of aerobic performance // J Int Soc Sports Nutr. 2020. 17- 57. https://doi.org/10.1186/s12970-020-00385-2
2. Lyudinina, A.Yu., Ivankova, G.E., Bojko, E.R. Priority use of medium-chain fatty acids during high-intensity exercise in cross country skiers // J Int Soc Sports Nutr. 2018. № 15 (57). P.77-82. DOI: 10.1186/s12970-018-0265-4
3. Lyudinina, A.Y.; Parshukova, O.I.; Bojko, E.R. n-3 Polyunsaturated Fatty Acids Are Associated with Stable Nitric Oxide Metabolites in Highly Trained Athletes // Cells 2024, 13, 1110.https://doi.org/10.3390/cells13131110
4. Parshukova, O.I., Varlamova, N.G., Potolitsyna N.N., Lyudinina, A.Y., Bojko, E.R. Features of metabolic support of physical performance in highly trained cross-country skiers of different qualifications during physical activity at maximum load // Cells. 2022, 11, 39. https://doi.org/10.3390/cells11010039.
5. Parshukova, O.I., Varlamova, N.G., Bojko, E.R. Nitric oxide production in professional skiers during physical activity at maximum load // Front. Cardiovasc. Med. 2020. Vol. 7. https://doi.org/10.3389/fcvm.2020.582021

FOCUS ON FEMALE ATHLETES ON SPECIFIC PHYSIOLOGICAL ADAPTATIONS TO HYPOXIA

Prof. Grégoire Millet[1]

[1]University of Lausanne

Each of the cerebral, ventilatory, cardiovascular, haematological and muscular adaptations to hypoxia has a specific time course that is important to monitor and control both during pre-acclimatization and during altitude training camp. Similarly, post-altitude variability in responses kinetics is paramount.

During his talk, based on 40 years of experience as professional athlete, then coach, physiologist and adviser of many elite athletes, Professor Millet will present an update overview of the current knowledge of the acclimatization processes in order to answer these important questions: so what? what does it mean for my athletes? what should I do or don't as a coach or support scientist?

Practical recommendations will be suggested, potentially paving the way for improved know-how in winter sports. Special focus will be on specific responses in female athletes and on potential sex-differences on adaptation to altitude training.

The key question we will try to answer is : do women have to train differently in altitude ?

BEYOND THE CLASSICAL "LIVING HIGH" PARADIGM IN WINTER SPORTS: LESSONS FROM SUMMER SPORTS

*Franck Brocherie * 1, Jonas Forot [2,3,4], Grégoire P Millet [3]*

[1] Laboratory Sport, Expertise and Performance (EA 7370), French Institute of Sport (INSEP), Paris, France [2] Scientific Department, Centre National de ski Nordique et de Moyenne Montagne, Prémanon, France [3] Institute of Sport Sciences, University of Lausanne, Switzerland [4] Scientific Department, Fédération Française de Ski, Annecy, France

Keywords: Hypoxia, heat, cross-adaptation

INTRODUCTION: Winter sports events are generally performed at low to moderate altitudes, requesting prior acclimatization/acclimation (the classical "living high" paradigm) to counteract the negative effect of lower oxygen availability (physiology) and reduced air resistance (skill components). However, the evolving boundaries of altitude/hypoxic training [1] as well as the potential of other environmental stress-based interventions (e.g. hyperoxia for recovery or heat for cross-adaptation) tested in summer sports contribute to an increase body of knowledge and evidence that could be translated to winter sports.

METHODS: The literature indexed on Pubmed related to environmental stress-based training in winter sports (n = 80) was searched and reviewed and further accompanied by our latest summer sport athlete-centered research involving environmental stress intervention to improve performance (6 endurance, combat and team sports, n = 92).

RESULTS/DISCUSSION: Besides acclimatization/acclimation approaches, passive modalities (e.g. ischemic pre-conditioning) and active modalities using either local (blood flow restriction) and/or systemic hypoxia (e.g. repeated-sprint training in hypoxia, resistance training in hypoxia) already benefited winter sports such as cross-country skiing or ice hockey [2, 3]. Further advancement from summer sports using the combination of chronic altitude/hypoxic exposure with acute hypoxic training [4, 5] or heat alternative for cross-adaptation emanating from the last summer Olympic preparation provide some new insights for physiological (hematological and non-hematological) adaptation and performance enhancement, potentially transferable to winter sports.

CONCLUSION: The continued evolution of winter sports contributes to the emergence of new training methods to improve athlete's preparation and/or performance. In addition, the findings from summer sports also open new training perspectives for many winter sports, with experience of the French teams for Paris 2024 paving the way for Milano Cortina 2026 and French Alps 2030.

REFERENCES:

[1] Girard, O. et al, 2020 Front Sports Act Living
[2] Faiss, R. et al, 2015 Med Sci Sports Exerc
[3] Brocherie, F. et al, 2022 Int J Sports Sci coach
[4] Brocherie, F. et al, 2015 Med Sci Sports Exerc
[5] Bouten, J. et al, 2023 Int J Sports Physiol Perf

SPINAL AND SUPRASPINAL EXCITABILITY DURING CROSS-COUNTRY SKIING USING V2 SKATING TECHNIQUE

Magdalena Karczewska-Lindinger[1], Stefan Lindinger[1], Harri Piitulainen[2], Alessandra Giangrande[2,3], Jarmo M Piirainen[2,4]

[1] LABIS-IIS ALBERTI, Bormio, Italy
[2] Faculty of Sports and Health Science, University of Jyväskylä, Jyväskylä, Finland
[3] LISiN, Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Torino, Italy
[4] Sport Technology Unit Vuokatti, Faculty of Sports and Health Science, University of Jyväskylä, Jyväskylä, Finland

Keywords: Nordic skiing, motor control, H-reflex, V-Wave

INTRODUCTION: Motor control has been divided into spinal and supraspinal control, which can be measured using H-reflex and V-wave methods, respectively (Aagaard et al. 2002, Nevanperä et al. 2023). Utilizing these methods in dynamic conditions are challenging since responses are sensitive with variation on neural behavior, constance of performance (skiing) techniques and distance between stimulating electrode and the nerve. The purpose of the study was to analyze repeatability of H-reflex and V-wave methods during cross-country skiing (XCS). In addition, the role of spinal and supraspinal control was evaluated especially in the gliding phase (balance control).

METHODS: Seven experienced skiers (27-49 yrs) performed 10-15 trials (3- minutes each) using V2 skate on roller skies (treadmill; 2° incline) with a velocity corresponding 85% of their maximal skiing velocity. Soleus muscle V-wave (normalized to M_{max}) was measured utilizing supramaximal stimulation intensity (150% M_{max}) at 1, 255 and 455 ms after the ground contact of the roller ski to measure the effect of supraspinal output during early contact phase, early gliding phase and the late gliding phase, respectively. H-reflex responses (conditioned with 15% M_{max}) were measured with identical delays to evaluate spinal level output.

RESULTS: Between day repeatability (ICC) was moderate to good for the V-wave and H-reflex 0,556-0,748 and 0,663-0,895, respectively. In both responses, there was significant main effect between the phases (V-wave F=4,529, $p<0.05$; H-reflex F=9,969, $p<0.001$) without significant interactions. V-wave responses increased significantly from contact phase to early gliding phase ($p<0.01$) with no changes between early and late gliding phases. Similarly, H-reflex increased significantly from contact to early gliding phase ($p<0.001$) with again no changes between early and late gliding phases.

DISCUSSION/CONCLUSION:

Stimulation techniques may be a potential tool to investigate motor control during XCS. Spinal output was higher during the gliding phase, likely due to increased supraspinal output, although the possibility of increased reflex loop output cannot be ruled out. Possible limitations of the methods are variation of the muscle length and of the pressure of the stimulation electrodes during skiing, which may be subject dependent behavior. Weaker skiers in pilot trials also showed a tendency to lower repeatability. This is to be further investigated evaluating the method applied to XCS.

REFERENCES:

Aagaard P. et al., 2002, J Appl Physiol
Nevanperä S. et al., 2023, Exp Brain Res

LONGITUDINAL ANALYSIS OF AEROBIC PERFORMANCE INDICATORS IN ELITE CROSS-COUNTRY SKIERS: AGE- AND SEX-DEPENDENT TRAJECTORIES ACROSS THE CAREER

*Elias Bucher** [1,2], *Jon P. Wehrlin* [1], *Grégoire P. Millet* [2], *Thomas Steiner* [1]

[1] Swiss Federal Institute of Sport, Magglingen, Switzerland; [2] Institute of Sport Sciences, University of Lausanne, Switzerland.

Keywords: VO_2max, lactate threshold, time-trial performance, mixed-effects models

INTRODUCTION: Elite cross-country (XC) skiers undergo standardized testing to monitor their performance development and to calibrate training prescriptions. However, the long-term progression of relevant performance indicators, such as maximal oxygen uptake (VO_2max), performance at the second lactate threshold (LT_2), and time-trial performance over an athlete's career remains unclear, with previous research focusing on the junior to U23 level [1]. This study aimed to investigate the longitudinal data from > 15 years of exercise testing with the Swiss XC ski national team to examine the trajectory of key performance indicators across the careers of male and female skiers.

METHODS: The longitudinal development of VO_2max, LT_2, and 24-minute double poling performance (24-min DP), described in further detail elsewhere [2], was analyzed in 72 male and 49 female current and former Swiss XC-ski national team athletes. The performance trajectories were modeled using mixed-effects approaches, with a linear random intercept for VO_2max, a linear random slope for LT_2, and a third-degree polynomial for 24-min DP. Fixed effects included age, sex, and their interaction, with random effects at the individual level. The study included 357 observations (n = 27 females, 48 males) for VO_2max, 911 (n = 46 females, 65 males) for LT_2, and 601 (n = 49 females, 70 males) for 24-min DP.

RESULTS/DISCUSSION: VO_2max in females showed a non-significant tendency to increase by 0.16 mL/kg/min per year (p=0.085), with no increase in males (0.03 ml/kg/min per year, p=0.627). Although males had a higher baseline VO_2max at age 18 (70.8 vs. 58.2 mL/kg/min, 21.6% difference), the rate of change with age was not significantly different between the sexes (p=0.259). LT_2 improved significantly with age for both sexes, with females gaining 0.09 test stages per year (p<0.001) and males showing a stronger age effect with 0.12 test stages per year (p<0.001). At age 18, males had a 28.9% higher baseline LT_2 (5.95 test stages vs. 4.62 for females). In the 24-min DP test, both males and females showed a significant linear improvement with age during the first years (p<0.001). However, there was a notable decrease in the rate of improvement in males, as indicated by the quadratic age term (p<0.001). On the other hand, females showed a consistent linear performance trajectory throughout their careers, with no significant quadratic age term (p=0.430). Female skiers showed a baseline performance of 3820 m at age 18, while this value was at 4788 m in males, with males outperforming females by 968 m (25.3%).

CONCLUSION: VO_2max, LT_2, and 24-min DP showed distinct developmental trajectories across age and sex in elite cross-country skiers. While VO_2max remained unchanged, LT_2 continuously increased throughout their career. On the other hand, 24-min DP followed a non-linear progression only in males, with a slowdown in performance improvement as they transitioned from the U23 to the senior age category. These results highlight the importance of high initial VO_2max at the junior level and the greater trainability of LT_2 and aerobic time-trial performance with the accumulation of specific training as athletes progress in their careers.

REFERENCES:

[1] Zoppirolli, C. et al, 2020 Front Sports Act Living
[2] Bucher, E. et al, 2023 Scand J Med Sci Sports

HIGHER ENERGY AVAILABILITY MAY SUPPORT HEMOGLOBIN MASS ADAPTATION DURING A 21-DAY PERIOD AT NORMOBARIC HYPOXIA AND NORMOXIA IN FEMALE SKIERS

Oona Kettunen, Titta Kuorelahti, Vesa Linnamo, Johanna K. Ihalainen & Ritva Mikkonen*

Vuokatti Sports Technology Unit, Faculty of Sport and Health Sciences, University of Jyväskylä, Finland

Keywords: altitude training, cross-country skiing, endurance athlete, nutrition

INTRODUCTION: Low energy availability (EA) may be detrimental to an athletes' health and performance [1], but the interaction between EA and altitude training adaptations warrants exploration. Therefore, the present study investigated EA during a 21-day period of normobaric "live high, train low" (LHTL) and examined whether athletes with positive hemoglobin mass (Hb_{mass}) responses had different EA compared to the athletes with neutral / negative responses.

METHODS: 10 female skiers completed a 21-day period (~18 $h \cdot day^{-1}$) of LHTL in normobaric hypoxia of ~2500 m while 11 female skiers formed a control group (CON) that lived and trained in normoxia. Hb_{mass} was assessed using a carbon monoxide rebreathing method and fat-free body mass (FFM) from bioimpedance measurement within 2 days before starting a LHTL/CON period (PRE) and within a week after LHTL/CON period (POST). An athlete was classified as *Hb_{mass}-responder* if Hb_{mass} increased by >1.7% from PRE to POST based on the typical measurement error reported for the CO rebreathing method [2] and others were classified as *Hb_{mass}-non-responders*. Energy intake (EI) was assessed using 3-day food logs, which were completed from the 10th to 12th day of the LHTL or CON period. Exercise energy expenditure (EEE) was assessed based on the duration and mean heart rate of the training sessions. Daily EA was calculated as: EA = (EI – EEE) / FFM. Differences between *Hb_{mass}-responders* and *non-responders* were analyzed with a two-way ANOVA with group (LHTL, CON) and response (*responders, non-responders*) as between-subject factors.

RESULTS: LHTL increased *Hb_{mass}* 3.3 ± 2.4% (7 *responders*, 3 *non-responders*) and CON 0.9 ± 2.3% (4 *responders*, 7 *non-responders*), but the main effect of group was not statistically significant (p = 0.38) showing no differences between the groups. *Hb_{mass}-responders* had similar EEE (p = 0.72) but higher EI (p = 0.034) and EA (p = 0.008, Figure 1) than *Hb_{mass}-non-responders* in both LHTL and CON. A total of three athletes had an infection during the study (Figure 1). All three had low EA (< 30 $kcal \cdot kg\ FFM^{-1} \cdot d^{-1}$).

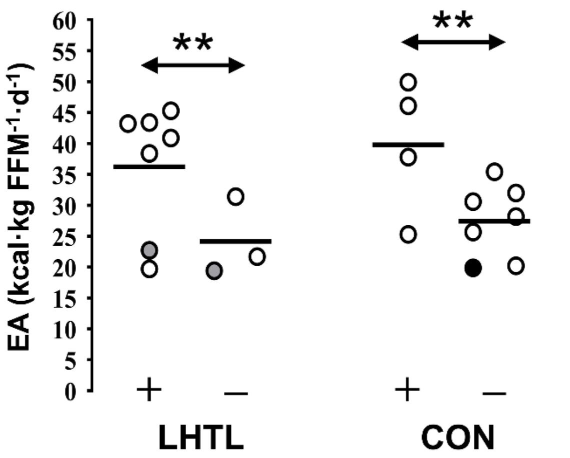


FIGURE 1. EA in *Hb_{mass}-responders* (+) and *non-responders* (–). The circles represent individual values, and the lines represent group means. An athlete who did not perform POST measurement due to infection is marked in black and two athletes who had shorter (16-18-day) LHTL period due to infection are marked in grey. ** Significant difference between *responders* and *non-responders* p<0.01.

CONCLUSIONS: Higher EA may support Hb_{mass} adaptations and healthy training days during 21 days of LHTL as well as during 21 days of normal training at sea level. These findings highlight the importance of adequate dietary intake to optimize hematological adaptations to training and hypoxia.

REFERENCES:

[1] Mountjoy, M. et al, 2023 Br J Sports Med
[2] Schmidt, W. & Prommer, N., 2005 Eur J Appl Physiol

AI-RACER: AN IMMERSIVE AI-ENABLED VR-TOOL FOR ALPINE SKI RACING

Björn Bruhin[1], Martin Bünner[2*], Fabien Délèze[3], Nicola Notari[4], Sébastien Guillaume[3], Samuel Schwyn[3]*

[1]Swiss-Ski, Worblaufen, Switzerland; [2]DAViS, Fachhochschule Graubünden (FHGR), Chur, Switzerland; [3]Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD), Yverdon-les-Bains, Switzerland; [4]Ostschweizer Fachhochschule (OST), Buchs, Switzerland;

Keywords: optimal racing line, optimal control theory, virtual reality, artificial intelligence, alpine skiing

INTRODUCTION: The choice of the racing line is a key success factor in alpine ski racing. Nevertheless, to define before the race a "proper" racing line for a given racing track remains a highly subjective process for coaches and athletes, as objective quality criteria for racing lines are not available. As such, the definition of racing lines and racing strategy is until now not accessible for scientific discussion opening up the room for myths and subjective rules-of-thumb. The aim of this work is to establish a formal procedure for the computation of optimal racing lines before the race. With this, we hope to introduce objective factors supplementing the already available subjective factors.

METHODS: On the basis of a physical model of an alpine ski racer and a 3D-measurement of the surface of the racing track, optimal control theory is applied to compute an optimal racing line for the ski racers. To this end, a nonlinear programming problem (NLP) is formulated with > 10'000 unknowns, and > 1 Mio. equality and inequality constraints, the solution of which is the optimal racing line. Additionally, the racing track is measured accurately with LIDAR- and photogrammetry- technology. With this, an accurate 3D-world could be created allowing to visualize the optimal racing line with Virtual-Reality-(VR)-technology, allowing for an highly immersive experience for the athletes.

RESULTS/DISCUSSION: The AI-RACER has been tested on World-Cup racing tracks with professional athletes, after the competion has taken place. The error in forecasting the finish time was below 1.0 – 2.0 s. The accuracy of the physical model is surprisingly high for gliding phases. The model for more complex skiing techniques, such as drifting or energy pumping, needs further improvements, though.

CONCLUSION: While not being perfect today, the AI-RACER opens up the space for advancements in the future. Clearly, there are promising future applications for racing as well as for training and education of young athletes.

OBJECTIFICATION OF THE RESULTS OF THE AGILITY-TEST THROUGH THE USE OF AI METHODS

*Andreas Huber * 1, Chris Hummel 2, Max Rieder [1], Peter Spitzenpfeil [2], Karlheinz Waibel [3]*

[1] Olympiastützpunkt Bayern, Munich, Germany [2] Applied Sport Science, Technische Universität München, Germany [3] German Ski Federation, Planegg, Germany

Keywords: alpine ski racing, testing, injury prevention, return-to-competition

INTRODUCTION: Since 2016, the agility test [1] has been used in performance diagnostic tests and in the return-to-sport process of the German alpine skiing, ski cross and ski freestyle team athletes. While the test has proven in practice to be very effective in the return-to-sport process, the assessment of both the two landings and the 15 jumps was subjective, with three categories each: good, average and bad. The subjective assessment is to be expanded, objectified and, ideally, replaced by an AI-supported, automated kinematic evaluation (Nemo, Simi Reality Motion Systems GmbH ©, Unterschleißheim, Germany).

METHODS: All attempts were filmed frontally by only one camera (2D). The video recordings made, went through the automated AI process and as a result the joint points were transformed to pixel coordinates. The quality of the landings was subjectively assessed analogously to Stensrud [2]: Performance was reported concerning lateral tilt of the pelvis (not significant – some – obvious), Valgus motion of the knee (no obvious – slightly – clearly) and medial/ lateral side-to-side movements of the knee during the performance (no – some – clear). For comparison, the position of the hip axis in relation to the shoulder axis (hip to shoulder) and to the horizontal (hip to horizontal), the leg axes in relation to each other and the knee movement during landing were calculated from the coordinates. To assess the jumps, the determined flight and contact times, 2D center of gravity in flight and contact times and the horizontal distance from the middle of the foot to the middle of the knee (distance foot to knee) during the contacts were used. The subjective assessment had the criteria of position of the foot and leg axes, stable body position and overall coordination.

RESULTS/DISCUSSION: The parameters determined showed a wide range in the results, greater than a rigid 3-point assessment. The quality of the valgus movement determination in the knee was sufficient. As of now, all results that were related to spatial expansion were more difficult to assess and therefore significantly less satisfactory.

CONCLUSION: Even if not all criteria were found automatically due to the limitation to a frontal video, additional features are already emerging to better assess the athlete, especially in the back-to-sport process. The next process will be the calibration of the videos (height and width of the first and last hurdle) and a rescaling as they get closer (captured by the fixed order of the jumps).

REFERENCES:
[1] Huber, A. et al (2020). Single leg jumps as resource to improve injury prevention and the return-to-competition-process. Science and Skiing VIII. Book of the 8th International Congress on Science and Skiing. S. 46-55.
[2] Stensrud et al (2011). Correlation between two-dimensional video analysis and subjective assessment in evaluating knee control among elite female team hand-ball players. Br J Sports Med 2011; 45:589–595.doi:10.1136/bjsm.2010.078287

TRAJECTORY FILTERING AND JUMP MODELLING IN SKI CROSS VR-APPLICATION

Samuel Schwyn[1], Fabien Délèze[1], Sébastien Guillaume[1], Björn Bruhin[2]*

[1] INSIT, Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD), Yverdon-les-Bains, Switzerland; [2] Swiss-Ski, Worblaufen, Switzerland;

Keywords: ski cross, trajectory filtering, ballistic, virtual reality

INTRODUCTION: In ski cross, jumps represent key phases of the race. Therefore, it is essential that they are realistically depicted when creating a first-person virtual reality (VR) application to replay a race in an immersive way. Currently, when a VR application is based on real trajectories, these are mostly measured using a GNSS receiver in single point positioning (SPP) mode, which provides an accuracy of about 2 to 6 meters for the horizontal and vertical components, respectively. As a result, GNSS SPP altitudes are not usable for such applications. When the athlete is not in flight phase, the digital terrain model can be appropriately used to predict the athlete's altitude. However, when the athlete is jumping, it is necessary to obtain their trajectory in the air through an appropriate ballistic calculation. The objective of this work is therefore to propose a solution to determine the complete trajectory (including during jumps) of an athlete by merging GNSS SPP positions, a digital terrain model, and a ballistic model in order to create a smooth and immersive VR experience in a realistic 3D environment.

METHODS: Two VR applications were developed. The first is a VR application to assist in the efficient determination of fused trajectories, and the second is an immersive first-person VR visualization for the ski cross track. To achieve this, a high-resolution 3D model of the ski cross track and its surroundings was generated using drone-based photogrammetric surveying. Additionally, the athletes' trajectories were measured using GNSS SPP technology.

The first VR application allows users to visualize the track and interactively set the jump origins on each obstacle. The fused trajectory is displayed in real-time in an immersive and dynamic manner, and it can be adjusted on the fly if necessary. The trajectory fusion algorithm is based on control theory, combining GNSS horizontal data with ballistic calculations that account for gravity and simple aerodynamic effects.

RESULTS/DISCUSSION: The initial results of the fusion algorithm are encouraging and have made it possible to determine realistic and usable trajectories for the VR application, benefiting both athletes and coaches. The VR application, which allows the adjustment of the jump-starting position as well as the initial impulse parameters, has proven to be effective and user-friendly. However, it would be feasible to automate some of these adjustments. The automation process and the data fusion for trajectory determination could also be improved by integrating data from accelerometers.

CONCLUSION: The developed tools allow for the easy determination of ski cross athletes' trajectories by merging GNSS SPP data, a digital terrain model, and a simple ballistic model. The methodologies developed can also be applied to other disciplines, such as alpine skiing or ski jumping, where the vertical component of the trajectories measured by GNSS SPP technology is insufficient.

THE EFFECT OF COURSE DESIGN ON SURROGATE MEASURES OF INJURY RISK IN WOMEN AND MEN WORLD CUP SKICROSS

*Linda Tomelleri [1], Ivar Hereide Mannsåker [1], Thibault Lachaize [2], Willemijn Wortelboer [3], Michael Lasshofer [4], Matthias Gilgien [1,5]**

[1] Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway [2] UFR Science et Montagne, Université Savoie Mont Blanc, Chambéry, France, [3] Human Movement Technology, The Hague University of Applied Sciences, Den Haag, Netherlands, [4] Athlete Health Unit, International Ski and Snowboard Federation FIS, Oberhofen, Switzerland [5] Center of Alpine Sports Biomechanics, Engadin Health and Innovation Foundation, Samedan, Switzerland

Keywords: Injury prevention, sports medicine,

INTRODUCTION: In skicross, the number and severity of injuries are among the highest and most serious in winter sports [1]. The specific aspect of skicross is the head-to-head racing during the finals and the course, which is made up of different types of obstacles. Previous research has linked injuries to three types of obstacles (jumps, turns and rollers) and the injuries were primarily caused by unintentional contact between skiers and personal error [2,3]. To provide a more comprehensive picture of the factors that might lead to injuries, this study assumed that surrogate measures of injury risk (hereafter named "events"), such as crashes, are related to actual injury risk. Based on this assumption this study investigated how course characteristics affected these injury risk metrics for women and men.

METHODS: During the 2023/24 season the connection between injury risk events and course characteristics were evaluated across five World Cup races (Innichen, Alleghe, St. Moritz, Reiteralm and Veysonnaz). For that purpose, human reviewers utilized TV footage of all final heats, for men and women, to pinpoint the location of such events. Crashing was defined as the event with the closest relation to true injuries, while out of balance, contacts and avoided contacts between athletes were defined as potential pre-conditions of crashing. The geometric attributes of the World Cup courses were logged using differential GNSS, facilitating the creation of digital terrain models, that were used to determine the nature and location of obstacles.

RESULTS/DISCUSSION: Men had more contacts, avoided contacts and out of balance events than women, while women and men had the same number of crashes. For women, the occurrence of crashes was the same for each type of obstacle, whereas for men most crashes occurred in turns. Women most often crashed with an out of balance event as a prerequisite, while for men the combination of an out of balance event and contact with another skier most often caused a crash.

CONCLUSION: Since women usually crash without interference to other skiers, the technical difficulty of the course itself seems to cause crashes while men seem to have a higher capacity to recover from out of balance and contact events than women. Since the courses are used by women and men, they need to be designed so that they are not too difficult for women but still challenging for men.

REFERENCES:

[1] Engebretsen, L. et al. 2012 Br J Sport. Med
[2] Randjelovic et al. 2014 Br J Sport. Med
[3] Brusveen, H. 2020. Norwegian School of Sport Sciences

SKI BINDING PERFORMANCE, BIOMECHANICS, TESTING, AND ENGINEERING DESIGN

Christopher A. Brown

Sports Engineering Lab, Mechanical and Materials Engineering Department, Worcester Polytechnic Institute, Worcester, Massachusetts, USA

Keywords: Axiomatic design, C-K theory, inadvertent release, ACL injuries

INTRODUCTION: A rigorous, science-based, engineering design method is used to explain how ski bindings can protect ACLs and avoid inadvertent release. Additionally, it shows how appropriate binding retention/release setting methods could be developed for elite skiers. In skiing, as other sports, awareness of injury mechanisms and how they can be avoided has not led to safer equipment. For decades concepts for ski bindings that could reduce ACL injuries and inadvertent release have been patented, presented, and published [1,2]. Yet, equipment designs from most manufacturers still do not address these problems. ACL injuries continue at unfortunately high rates. Inadvertent release problems are addressed by increasing release settings and increasing injury risks. Sports science and sports medicine communities could foster more innovation by promoting publication and presentation of design work. This could encourage dialog, activity, and investment required to develop and realize design innovations.

METHODS: Using Suh's design theory and method [3] with C-K theory [4], the best design parameters (DPs), i.e., physical solutions, are developed and selected using Suh's two design axioms. One maintains the independence of functional requirements (FRs), and two minimizes the information content. Solution neutral FRs are formulated based on needs. Corresponding DP candidates are sought to fulfill them. Top-down, parallel FR-DP hierarchies of increasing detail are developed. Decomposition equation tests validity to be collectively exhaustive and mutually exclusive. Design equations show how DPs are adjusted to get FRs into functional tolerance. Care is taken in formulating and understanding good FRs, which are required to develop good solutions. Viability is established through compliance with Suh's design axioms.

RESULTS/DISCUSSION: FR-DP decompositions are presented as actionable, intent-solution, design representations. FR1 is to transmit performance loads with high fidelity. FR2 is to absorb energy that would otherwise increase loads beyond those for safe performance. FR3 is to avoid inadvertent release. DPs 1-3 comprise stiff-soft, load-limiting spring systems. Displacement to release and the loads to initiate displacement prior to release can be adjusted independently. Plate assemblies under bindings can provide displacement prior to release. An FR4 to limit combined valgus-inward-rotation (CVIR) loads, known to stress the ACL, can be fulfilled by supplementing current bindings with a vertical rotation axis in front of the toe. This DP4, can be integrated in the plates [2]. Bindings mounted on plates can fulfill release functions, while plates improve retention and reduce CVIR type ACL injuries. Performance loads for elite skiers could be functions of skier strength in addition to mass. Retention needs increase with speed. Research on correlations between strength tests, performance loads, and speed can test this hypothesis and establish functional relationships for setting response loads.

CONCLUSION: Ski bindings can be advanced using rigorous engineering design theory and methods to develop and test concepts. ACL injuries and inadvertent releases can be reduced. Papers describing theoretically validated, viable design solutions can lead to improvements in athlete safety. Design papers should be valued similarly with other kinds of research papers.

REFERENCES:

[1] Brown, CA 1985 *Skiing Trauma and Safety: Fifth International Symposium*. *ASTM International*.
[2] Madura, JM et al., 2014 *Science and Skiing VI*.
[3] Suh, NP, 1990, *Principles of Design*, Oxford Press, New York.
[4] Le Masson, P et al., 2017 *Design Theory*, Springer.

VALIDATION OF A BIOFIDELIC SENSORIZED KNEE FOR SKI FALL SIMULATIONS IN A DYNAMIC MULTIAXIAL TEST BENCH

Nicola Petrone [1], Mattia Scapinello[1], Francesco Cipolat-Mis[1], Nicolò Guidolin[1]*

[1] Department of Industrial Engineering, University of Padova, Padova, Italy

Keywords: knee injuries, knee surrogate, dynamic simulations, skiing safety

INTRODUCTION: It's well established how knee joint shows the highest injury incidence both in competitive and recreational modern alpine skiing. Identification of protective strategies involving intervention at the bindings [1] or other protective devices such as passive knee braces [2] or active airbag systems represent the possible prevention directions. The present work reports progresses in the validation of a biofidelic synthetic knee surrogate equipping a multiaxial test bench designed for simulating dynamic knee injuries mechanism and supporting the development of effective protection devices such as knee braces.

METHODS: The leg surrogate (3D printed surfaces covered with silicon layers to mimic soft tissues) includes a biofidelic knee with sensorised ACL/PCL/MCL/LCL ligaments, Tibial Plateaus and Quadriceps Tendon (Figure 1.a). Static tibial axial and shear loadings, as well quadriceps contraction can be applied together with static, cyclic and dynamic knee flexion, ab/adduction and rotation rapid movements. Loads can be sensed by two multiaxial 6-axis load cells, one at the proximal tibia and one at the proximal thigh. Complex loading conditions as in [3] were reproduced in angle control at increasing flexion angles, ACL and PCL measured loads were compared with available literature results.

RESULTS/DISCUSSION: Bench test results under Anterior Shear, Internal Tibial Torque and their combinations (Figure 1.b) obtained by the bench surrogate showed good agreement with the cadaver average data found in literature (Figure 1.c) [3]. As well, external torque tests results (Figure 1.d) showed fair agreement with literature data (Figure 1.e), with a tendency to PCL overloading. Tests with additional Quadriceps contraction showed less agreement in the early flexion degrees. Artificial ligaments pre-tensioning and lubrication conditions resulted the major issues of tests preparation and conduction.

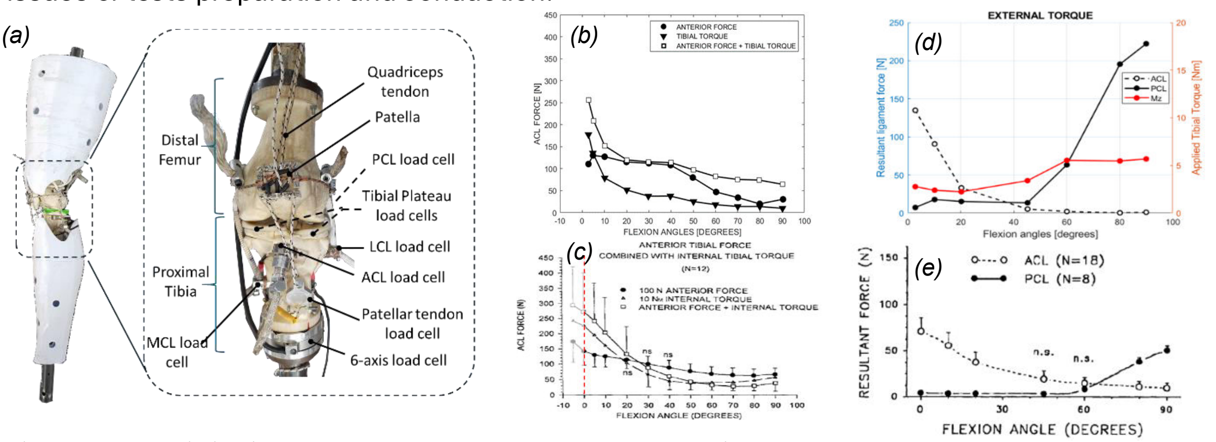


Figure 1: (a) the Biofidelic Knee surrogate, (b-c) ACL loads under Anterior Shear and Internal Torque, (d-e) ACL and PCL under External Torque. (Experiments (Top) Vs Literature (Bottom))

CONCLUSIONS: Based on the present results, the bench can be used to simulate high speed kinematic actions on the surrogate leg, to evaluate the protection offered by knee braces or safety bindings.

REFERENCES:

[1] Senner, V. et al. (2013), Sports Engineering.
[2] Supej, M. et al. (2017), British Journal of Sports Medicine, 51(1).
[3] Markolf K., et al., Journal of Orthopaedic Research, 1995.

MANAGING THE MALALIGNED SKIER ON AND OFF HILL

Carl Petersen[1]

[1]City Sports + Physiotherapy Clinic, Vancouver, Canada

carlpetersen2411@gmail.com or carl@citysportsphysio.com

Keywords: Malalignment syndrome, hip and core training, injury prevention

INTRODUCTION

Very few competitive skiers or athletes participating and training in other sports make it through an entire season without experiencing some form of pain or injury associated with kinetic chain weakness and/or malalignment. Malalignment syndrome of the pelvis and hips can have far reaching effects on core stability and strength of the lower and upper extremities in skiers leading to potential performance deficits and injuries. Literature exists on the practical treatment and exercise guidelines for prevention and maintenance of malalignment syndrome [1] [2] [3]]. Unfortunately, many medical practitioners and other primary health care providers are not aware of this condition, or do not have the training to diagnose and treat it effectively. Malalignment is an unrecognized cause of 50-60% of lower back and extremity injuries and is present in over 80% of all adult athletes [4] [5] but only about one-third of them have complaints that unbeknownst to them, are caused by the malalignment.[6] It is most common in athletes that engage in significant asymmetrical and rotational sports that require deceleration forces including skiing. The movement problems encountered by the alpine skier revolve around changing directions and maintaining balance at high speeds while undergoing a variety of horizontal and vertical disturbances. [7] This session will help participants understand this condition and how to do an assessment to identify the most common presentations of malalignment syndrome including bony alignment, length-tension and quick functional stability checks. [8] It will explore common implications affecting skiers during on and off hill training and offer self correction, treatment, training and recovery rules and tips to minimize its impact on skiing performance including: re-align the lower and upper links: regain and maintain muscle length; release the soft tissue and re-connect the core.

CONCLUSION

As primary health care providers we must avoid looking at an injury in isolation and ensure we examine the spine, pelvis and entire kinetic chain for signs of malalignment. The intention of this session is to create an awareness of the malalignment syndrome and the of type of problems this can create for skiers both on and off hill. If there is inadequate development of the stable platforms of the lower and legs and upper core and arms athletes may be at risk of injury.[9] and once injured they are likely to take longer to recover, or may even fail to do so at all [4] [5] Over time, skiers can learn to recognize the subtle changes that may occur upon recurrence of malalignment, such as a change in walking or running gait, changes in ease of multi-directional movement, or abnormal tension in the myofascial tissues. Early recognition of malalignment allows for earlier treatment, correction, and ideally an avoidance of the discomfort and associated problems. The combination of changes that constitute malalignment syndrome can interfere with recovery from an injury and ability to perform. Skiers who are not able to maintain alignment will have difficulty progressing in the technical and physical training aspects and may have to decrease volume and intensity of skiing as a result and, in some cases, may have to abandon the sport altogether.

REFERENCES:

[1] Petersen C, Sirdevan M, Schamberger W, Morrell R (2004) Back Problems & The Malaligned Athlete in C. Petersen Fit to Ski Fit-Practical Tips to Optimize Dryland Training & Ski Performance. Fit to Play Int. Inc. Vancouver, Canada. Pages: 208-222

[2] Petersen C, Sirdevan M, Schamberger W, Morrell R. (2009) Part 4-Recovery & Injury Prevention-Healthy Back in C. Petersen. Fit 2 Ski –A Complete Guide to Fitness. BK Media/Fit to Play Int. Inc. Vancouver. pages: 160-169

[3] Petersen C. & Schamberger W. (2013) Managing Malalignment Syndromes. J Medicine & Science in Tennis; (18) 3. Pages96-106

[4] Schamberger W. (2002) The malalignment syndrome: Implications for medicine and sport. Churchill Livingstone 2002.

[5] Schamberger W. (2013) The Malalignment Syndrome: Diagnosing and treating a common cause of acute and chronic pelvic, limb and back pain. Churchill Livingstone 2013.

[6] Schamberger, W. (2020) Read My Hips! Friesen Press. Victoria, Canada 2020.

[7] Lutgens, K., Deutsch, H., Hamiliton, N. 1992. *Kinesiology Scientific Basis of Human Locomotion*. 8th ed. Brown & Benchmark, Dubuque, Iowa.

[8] Petersen C, (2009) Part 3-Dynamic Stability Tests (lower core & legs) C. Petersen. Fit 2 Ski –A Complete Guide to Fitness. BK Media/Fit to Play Int. Inc. Vancouver. pages: 153-157

[9] Petersen C. & Nittinger N. (2013) Connecting the Core-Exercises to Enhance Stability. J. Medicine & Science in Tennis; Feb: Vol:18, No.1

3D KINEMATIC AND MECHANICAL ENERGY IN FREESTYLE CROSS COUNTRY SKIING (XCS) DURING SPRINT WORLD CUP RACES

Arrigo Canclini[1], Antonio Canclini[2], Andrea Besseghini[1], Guido Baroni[2], Stefan Lindinger[1], Magdalena Karczewska-Lindinger[1], Renzo Pozzo[1,3]

[1] LABIS-IIS ALBERTI, Bormio, Italy [2] Politecnico Milano, Italy [3] DDAME Un. Med., Udine, Italy

Keywords: cross-country skiing freestyle, G3 G4 skiing gears, 3d analysis, Mechanical Energy

INTRODUCTION: The "new" freestyle (FT) in XCS was formally introduced in 1985 in specialized races. In the '90s several studies have been conducted in an attempt to describe the most relevant aspects of XCS freestyle, but the kinematic information is generally limited over the full velocity range. More recently Stöggl (2010), Andersson (2010), Lindinger (2011) compared biomechanical characteristics of the main skating techniques identified as gears G1-G5 as proposed by Nilsson (2004). The purpose of this work was to analyze the 3D kinematics and its changes of the main gears (G3 & G4) performed by elite skiers during sprint World Cup races in the last decade and to calculate energy recovery parameters.

METHODS: The data collection was performed in 2012 (Dobbiaco) and 2023 (Livigno) during WC-XCS individual Sprint Qualification FT races. In the 2012 race a total of 11 male skiers (ranking 1-22) were analyzed on flat sections where the athletes performed G3 or G4. In the 2023 race, in similar conditions of flat terrain, all the 30 skiers qualified for the heats were analyzed where 16 performed G3 and 14 performed G4.

RESULTS/DISCUSSION: Linear kinematic and angular parameters were calculated for each athlete (Table 1) as their mean values averaged over several cycles for each race. For the CoG Velocity we found some significant differences between G3 and G4. The CoG velocity in G4 was lower than in G3 about 4%, in 2012, and 9%, in 2023. The faster skiers have lower cycle time/higher cycle rate, in both strides: G3 (r=0.62) and G4 (r=0.66). The corresponding energy recovery indices are reported in Table1. We found a significant decrease of the R% between the 2012 and 2023 races: R% is lower 36% for G3, and 50% for G4.

Year/Terrain/Technique – gear	2012 Flat - G3	2012 Flat - G4	2023 Flat - G3	2023 Flat - G4
Gender, Subject N – number of cycles	MALE, N = 6 - 4 c.	MALE, N = 5 - 2 c.	MALE, N = 16 - 4 c.	MALE, N = 14 - 2 c.
CL (m) (cycle length)	7.32 ± 0.32	11.56 ± 0.58	8.16 ± 0.01	12.20 ± 0.17
CT (s) (cycle time)	0.85 ± 0.05	1.31 ± 0.08	0.91 ± 0.03	1.50 ± 0.04
Vave (m/s)	9.13 ± 0.29	8.78 ± 0.23	8.97 ± 0.34	8.14 ± 0.34
CoG Vert. Displacement (m)	27.42 ± 1.53	30.12 ± 2.41	0.23 ± 1.01	26.88 ± 1.03
% Time-Poling / CT	26% ± 2%	20% ± 2%	27% ± 2%	17% ± 1%
Elbow Angle (°) at PP	69 ± 5	69 ± 15	59 ± 6	75 ± 16
Elbow Angle (°) min	63 ± 4	55 ± 23	54 ± 5	69 ± 25
Trunk Angle (°) at PP	36 ± 2	36 ± 5	36 ± 4	44 ± 1
Poles Angle (°) at PP	17 ± 4	13 ± 4	12 ± 1	12 ± 2
Energy Recovery indices - variables				
R% energy recovery (%)	52% ± 12%	54% ± 9%	33% ± 11%	27% ± 5%
R cyc R(t) over the entire cycle (%)	44% ± 4%	46% ± 7%	39% ± 16%	30% ± 1%
R pro R(t) during the prop. phase (%)	11% ± 6%	10% ± 6%	10% ± 4%	8% ± 2%
R swi R(t) during the swing phase (%)	32% ± 5%	36% ± 5%	30% ± 13%	22% ± 1%

Table 1: Kinematic and Mechanical Energy parameters

CONCLUSION: Skiers that adopted the G3 technique were faster than G4-skiers. Moreover we found that the faster skiers, in G3 and G4, have a longer cycle rate. The skiers adopted to a different strategy to perform the poling with respect to the trunk, shoulder and elbow angular variations. In the Double Poling (Canclini 2021) we calculated similar values of R% (32%) only for the 2° slope.

REFERENCES:

[1] Canclini Ar. et al, 2021 J of Science in Sports and Exercise
[2] Lindinger S., 2011 European Journal of applied physiology

INFLUENCE OF POLE LENGTH ON METABOLIC AND KINEMATIC OUTCOMES IN CROSS-COUNTRY SIT-SKIERS

Sage Blickensderfer, Madeline Inman, Dayne Jarrett, James Becker*

Department of Food Systems, Nutrition, and Kinesiology, Montana State University, Bozeman, Montana, United States.

Keywords: pole length, sit-skiing, Para Nordic, double-poling

INTRODUCTION: Unlike able-bodied skiers, sit-skiers rely solely on poling for forward propulsion. Thus, any changes impacting poling mechanics may have a large influence on sit-skier performance. While able-bodied skiers show a negative correlation between oxygen uptake and pole length [1], whether this is also true in sit-skiers remains unknown. Manipulating pole length may also influence cycle kinematics [2], a change with potential direct bearings on performance as faster sit-skiers have longer cycle lengths. Given these gaps in knowledge, the purpose of this study was to evaluate the metabolic and kinematic effects of changing pole lengths on Para Nordic sit-skiers.

METHODS: Six elite Para Nordic sit-skiers participated in this study. Oxygen consumption and pole kinematics were recorded while skiing on a roller ski treadmill using four different pole lengths: habitual (H), ~ 2.5 cm shorter (S), ~ 2.5 cm longer (L1), and ~ 5.0 cm longer (L2). All trials were four minutes at a constant 3.5% grade, with order randomized. Oxygen consumption was measured using a wearable metabolic cart while IMUs were placed on the poles, just distal to the grip, and used to calculate cycle time (CT), cycle rate (CR), cycle length (CL), plant time (PT), and swing time (SW). Linear mixed-effects models with Tukey post hoc tests were used to evaluate the effects of pole length on dependent variables.

RESULTS/DISCUSSION: There were no significant fixed effects of pole length for any of the physiologic variables (all $p > .05$). However, there were significant fixed effects of pole length for CT ($p < .001$), CR ($p < .001$), CL ($p < .005$), PT ($p < .001$), and SW ($p < .005$, Table 1). Pairwise comparisons showed that CT, CL, PT, and SW all increased from the H condition to the L2 condition, while CR decreased (all $p < .05$, Table 1).

Table 1. Mean and standard deviations for poling kinematics across pole lengths.

Variable	Shorter	Habitual	Longer 1	Longer 2
CT (s)	1.36 ± 0.14[a]	1.38 ± 0.16[a]	1.42 ± 0.20	1.5 ± 0.22
CR (Hz)	0.74 ± 0.08[a]	0.74 ± 0.09[a]	0.72 ± 0.11	0.68 ± 0.10
CL (m)	3.49 ± 0.76[a]	3.48 ± 0.66[a]	3.59 ± 0.58[a]	3.69 ± 0.76
PT (s)	0.61 ± 0.10[a]	0.61 ± 0.11[a]	0.62 ± 0.13	0.66 ± 0.12
SW (s)	0.76 ± 0.09[a]	0.77 ± 0.09[a]	0.79 ± 0.09	0.84 ± 0.14

[a] Indicates a statistical difference from L2 ($p < 0.05$)

CONCLUSION: Changing pole length does not influence metabolic cost but does affect cycle kinematics in sit-skiers. Increasing pole length may be one way to improve efficiency in sit-skiing with no additional metabolic cost. However, it is important to consider that this study was performed on a ski treadmill at a set speed and grade, and thus may not reflect the variable conditions found on snow or mixed terrain courses.

REFERENCES:

[1] Onasch, F et al, 2017 J Appl Biomech
[2] Bernardi, M. et al, 2013 J Electromyogr Kinesiol

THE EFFECT OF SITTING POSITION ON SIT-SKI PERFORMANCE ON A TREADMILL AND IN A SKI ERGOMETER - CYCLE CHARACTERISTICS AND PHYSIOLOGICAL PARAMETERS: A CASE STUDY

*Ville Sampolahti * 1, Vesa Linnamo 2, Olli Ohtonen [1,2]*

[1] Vuokatti Ruka Sports academy, Vuokatti, Finland [2] Sports Technology Unit, Faculty of Sport and Health Sciences, University of Jyväskylä, Vuokatti, Finland

Keywords: Paralympic sit-skiing, cycle characteristics, sitting position, trunk control

INTRODUCTION: In sit-skiing, impaired athletes are classified into five classes based on the evaluations of their trunk control (LW10, LW10.5, LW11, LW11.5, LW12). A calculation system in which certain percentages are deducted of the competition finishing time (14.0%, 10.0%, 6.0%, 4.0%, 0.0%) has been created. [1] Two commonly used sitting positions are "kneeing" (KL) and "knee-high" (KH) positions [2]. Studies on biomechanical patterns and performance between classified athletes have mostly been conducted under laboratory conditions and have reported many positive patterns of KL for sit-skiing performance. [2,] In the ski ergometer, the effect of chancing sitting position in able-bodied athletes on performance in physiological and biomechanical parameters has been reported to be 7-15% favoring KL position [3]. The purpose of the present study wanted to measure the effect of sitting position on sit-skiing performance on a treadmill because it could simulate natural conditions better than in the ski ergometer.

METHODS: The athlete was LW11 classified female sit-skier, who had used KH position ten years, before one year of training in the KL position. In the ski ergometer, the athlete performed a maximal power test and on a treadmill, a maximal oxygen uptake test and performance tests for speed and uphill till exhaustion. Cycle length (CL), cycle time (CT), cycle rate (CR) and Blood lactate (B-La) were measured from treadmill tests. Maximal oxygen uptake VO_{2peak} (ml/kg/min), oxygen consumption (VO_2, l/min) and ventilation (VE, l/min) were measured during maximal oxygen uptake test.

RESULTS/DISCUSSION: 7.0%, 6.0% and 5.4% greater time to exhaustion in treadmill tests (maximal oxygen uptake test, speed test & uphill test respectively) and 14.4% higher power output in the ski ergometer in the KL position were observed. Higher CL and CT with lower CR were recorded in the KL position. The greatest difference in lactate ($B\text{-}La_{peak}$) was after the maximal test; 42,5% higher in the KL than in the KH position. There were no differences in $VO_{2\ peak}$, Ventilation was 6.0% higher in KH than in KL. A study with abled-bodied athletes reported the differences between the sitting positions to be 7-15% in the ski ergometer in physiological and biomechanical patterns [3], which is in line with the present study. The differences between the positons increase when the load increases and are caused by better ability to use upper body in the KL position. [2;3] The differences between the positions are greater than the differences between the classes.

CONCLUSION: Based on the findings of previous studies and this case study, it is highly recommended for the athletes to use KL position in sit-skiing. Unfortunately using KL position is not possible in lower classes (LW 10, LW10.5 and mostly LW11) due to their impairments and control of trunk abilities.

REFERENCES:

[1] International Paralympic Committee, 2017 World Para Nordic skiing—classification rules and regulations
[2] Rosso, V. et al, 2019 J Sports Eng Tech
[3] Lajunen, K. et al, 2020 Front Sports Act Living

A STUDY OF TAKEOFF MOTION IN SKI JUMPING USING PRINCIPAL COMPONENT ANALYSIS AND COMPUTATIONAL FLUID DYNAMICS

Shin Ikeda [1], Tokimasa Shimada [1], Rahul Bale [1,2], Tomoya Ueno [3], Keizo Yamamoto [3], Makoto Tsubokura [1,2]

[1] Graduate school of system informatics, Kobe University, Kobe, Japan [2] RIKEN-Center for Computational Science, Kobe, Japan [3] Graduate school of lifelong sport, Hokusho University, Ebetsu, Japan

Keywords: Ski Jumping, CFD, PCA, Trunk Angle

INTRODUCTION: The motions of ski jumping are divided into four parts: in-run, takeoff, flight, and landing. The takeoff motion in which largely change jumpers' posture in a short time of about 0.2~0.3 seconds is considered to strongly affect the performance. However, suitable takeoff motions have not been biomechanically and aerodynamically identified. Therefore, in this study, we first constructed a simulation framework that can reproduce detailed posture changes during takeoff using markerless motion capture. Next, the various jumps are classified with principal component analysis. The purpose of this study is to clarify the relationship between postural change during takeoff and the unsteady aerodynamic forces using the constructed framework.

METHODS: A total of 640 actual takeoff motions of 80 athletes were recorded. The 3D posture data were acquired using markerless motion capture application (Theia3D). Next, using the obtained motion data, a principal component analysis (PCA) was applied to the time series data of angle of attack (AOA) of trunk to classify the takeoff motion data. Finally, 3DCG animations of representative motions among the classified ones were created, and the unsteady aerodynamic forces acting during each takeoff were analyzed using Computational Fluid Dynamics (CFD) framework [1].

RESULTS/DISCUSSION: PCA showed that it is important to keep the displacement of the AOA of trunk within the certain range for exceeding the K point. And also, the takeoff motions for exceeding K point have the difference in the overall size of the AOA of trunk. Therefore, we selected several trials with different AOA of trunk among trials over K-point and analyzed the unsteady aerodynamic forces by CFD (Figure 1). As a result, it was found that different aerodynamic characteristics exist among the trials exceeding K-point.

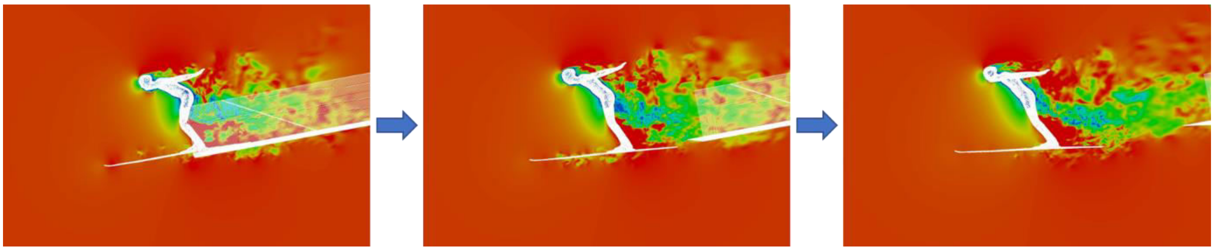


Figure 1 Velocity Visualization Diagram

CONCLUSION: Through this study, it is concluded that suitable takeoff motion in ski jumping is closely related to AOA of trunk displacement, and differences in aerodynamic characteristics exist among suitable takeoff motions.

REFERENCES:

[1] Yamamoto K, et al. "Numerical study of transient aerodynamic forces acting on a ski jumper considering dynamic posture change from takeoff to landing." Sports Biomechanics (2022): 1-15

TECHNIQUE ADAPTATION AT VARYING FRICTION IN CROSS-COUNTRY SKI SKATING

Gustav Hindér *,1, *Markus Akne Vieider* 1, *Joakim Sandberg* 1, *Andreas Almqvist* 1, Roland Larsson 1

1Department of Technology and Mathematics, Luleå University of Technology, Luleå, Sweden.
* Corresponding Author: gustav.hinder@ltu.se

Keywords: Cross-country skiing, Skiing technique, Advanced motion sensor,

INTRODUCTION: The varying snow conditions in cross-country skiing races lead to significant changes in the resistive forces caused by ski-snow friction. Previous studies have examined how this affects skiers while skating on snow [1,2] and roller skis on a treadmill [3], but somewhat conflicting results have emerged. A common factor in these studies is that skier velocity was restricted. This study aims to investigate how cross-country skiers adjust their technique across varying resistive forces, on both traditional and roller skis, using perceived exertion and heart rate as a controlled factor to simulate a race-like situation.

METHODS: The study involved 5 to 8 national-level cross-country skiers who participated in three tests conducted under different conditions: cold, hard-packed snow (-16ºC), warm, soft snow (3ºC), and on a roller-ski track (10ºC). Each athlete alternated between fast and slow skis, performing three intervals with each pair, while maintaining a self-selected skiing intensity corresponding to their threshold pace. Motion data were collected using advanced inertial measurement units (IMU) and GPS sensors (ASI, Switzerland) along a predefined flat track segment of 140 meters (approximately 10 cycles per segment). Cycle duration, cycle length, and velocity were calculated using Archinisis software (Archinisis, Düdingen, Switzerland). Data were analysed using paired t-tests to determine significant differences in technique adaptations between the fast and slow skis.

RESULTS/DISCUSSION: The G3 segment data presented in Table 1 showed no significant change in cycle duration between fast and slow skis. However, longer cycle lengths and higher speeds were observed with faster skis. This suggests that athletes adapt by increasing cycle length rather than altering skiing frequency. These results somewhat contradict the findings of Ohtonen et al. [1], where skiing frequency increased with higher friction at constant speed, indicating that increased intensity leads to higher frequency. Moreover, when comparing roller skiing with snow skiing, similar cycle data were recorded, despite nearly double the friction coefficients. This difference points to varying friction mechanics between gliding and skating phases on snow and asphalt.

Table 1. Mean and standard deviation for G3 segment data across the three test conditions.

	Cold hard-packed snow				Warm soft snow				Roller skis			
	COF [-]	Dur. [s]	Len. [m]	Vel. [m/s]	COF [-]	Dur. [s]	Len. [m]	Vel. [m/s]	COF [-]	Dur. [s]	Len. [m]	Vel. [m/s]
Fast	0.060	2.00±0.11	12.39±1.45	6.47±0.76	0.054	2.02±0.14	13.80±1.23	7.08±0.62	0.023	1.99±0.12	14.22±1.54	7.25±0.69
Slow	0.065	1.98±0.12	11.59±1.29	6.12±0.68	0.055	2.01±0.14	13.02±1.45	6.71±0.66	0.031	1.99±0.11	12.54±1.47	6.41±0.72
p-val.		0.052	0.000	0.000		0.898	0.038	0.003		0.708	0.000	0.000
Stat.		No	Yes	Yes		No	Yes	Yes		No	Yes	Yes

CONCLUSION: The study concludes that cross-country skiers primarily adjust their G3 skating technique by increasing cycle length while maintaining a constant skiing frequency when using faster skis and sustaining a constant intensity. The findings also highlight the need for further research into the friction dynamics of roller skiing. This knowledge may help optimize skiing techniques for various environmental conditions, contributing to enhanced race performance.

REFERENCES:

[1] Ohtonen, O., et al., 2013. Int J Sport Sci & Coach
[2] Myklebust, H., 2016.
[3] Ainegren, M., et al., 2009. Sports Eng.

THE DEVELOPMENT PROCESS OF BRINGING JUNIOR TALENTS TO THE WORLD-CLASS STAGE IN CROSS-COUNTRY SKIING

Øyvind Sandbakk[1,2]

[1]Centre for Elite Sport Research, Department of Neuromedicine and Movement Science, Norwegian University of Science and Technology, Trondheim, Norway
[2]School of Sport Science, UiT The Artic University of Norway, Tromsø, Norway

In this keynote, I will discuss key elements of a comprehensive athlete development system in cross-country skiing, drawing on both research and practical experience. Central to an effective development system is a shared training philosophy and a common understanding of the demands of the sport, aligning all stakeholders—athletes, coaches, and support teams—throughout an athlete's career. By conducting gap analyses to assess current athlete capabilities against long-term goals, individualized training plans are developed to systematically address these gaps. The periodization of volume, intensity, and the use of different exercise modes must ensure that each session meets its intended objectives while balancing load and recovery to facilitate optimal training adaptations. Regular coach-athlete evaluations and debriefs facilitate continuous learning and improvement, helping athletes to refine their individual approaches and optimize training quality. In addition, the integration of robust monitoring and evaluation systems is important to ensuring long-term performance development. Regular testing, documentation, and feedback loops allow for timely adjustments to training plans, minimizing risks of overtraining and underperformance. In this context, attention should also be given to critical recovery practices, including sleep and nutrition. Establishing a development culture also involves fostering an environment of trust, respect and joy. Coaches play a pivotal role in this process, acting as both leaders of teams and mentors by planning and overseeing individual athletes' training, providing real-time feedback, and engaging them in reflective discussions. Additionally, coaches must prioritize preventive health measures, such as injury prevention strategies, energy availability monitoring, and mental health support, to promote sustainable performance development. Finally, I will underscore the importance of maintaining a holistic perspective on athlete development. Athletes should not only be supported as competitors but also as individuals, with attention to their academic, social, and personal growth.

Hopefully, this keynote will provide actionable insights into high-quality athlete development systems, fostering environments where young cross-country skiers are given the opportunity to reach their full potential.

COACHING SNOWBOARD TRICKS: DO BIOMECHANICAL DATA ALIGN WITH EXPERT INSIGHTS?

*Lina Fay *[1], Christian Merz [2,3], Matthias Thelen [2], Felix Friedl [3,4] and Lars Donath [1]*
[1] Institute for Exercise Science and Sport Informatics, German Sport University Cologne, Cologne, Germany; [2] Institute of Biomechanics and Orthopaedics, German Sport University Cologne, Cologne, Germany; [3] Department Strength, Power & Technical Sports, Institute for Applied Training Science, Leipzig, Germany; [4] Department of Sports Science, Faculty of Humanities, Otto-von-Guericke University, Magdeburg, Germany

Keywords: snowboard halfpipe, off-snow, coach`s eye, biomechanics

INTRODUCTION:

In freestyle snowboarding, particularly in the discipline halfpipe, athletes perform highly technical aerial movements with increasing rotation [1], requiring precise body control and landing techniques. Trampolines provide a safe environment for refining these techniques [2], with coaches offering feedback based on visual cues. While research has focused on the biomechanics of the landing phase during on-snow training [3], the cues coaches use to analyze tricks during off-snow training on trampolines remain largely unexplored. Until now, no studies have systematically investigated how coaches assess tricks or whether these assessments align with biomechanical measurements. Therefore, this study aims to analyze which visual cues coaches use to evaluate snowboard tricks performed on trampolines, explore whether these cues are biomechanically measurable, and how coach evaluations compare with athlete self-assessments.

METHODS: Four elite male snowboard halfpipe athletes (age: 23 ± 4 years; weight: 74 ± 8.8 kg; height: 178 ± 7.8 cm, experience Snowboard Halfpipe: 10 ± 9 y), national team members who compete or have competed at the international level (Welt cups), performed a total of 584 tricks on a freestyle trampoline using a bounce board, with the amount of rotation ranging from 360° to 900° in different direction. A national coach of snowboard halfpipe (age: 28 years; national license; coach experience 5 y) and the athletes themselves judge the quality and execution errors of the tricks based on a questionnaire. The body position was captured by a motion capture system (Xsens, Nederland, 18 IMU, 240 Hz).

RESULTS/DISCUSSION: The coach focused primarily on 13 cues, with the front leg receiving the most attention, followed by gaze and upper body cues (s. Figure 1). The movement flow ($t = -3.2$; $p < 0.001$) and difficulty ($t = 9.53$; $p < 0.001$) showed statistically significant differences between coaches and athletes. Both coaches and athletes agreed on the feasibility of transferring tricks to on-snow conditions, suggesting that trampoline training effectively prepares athletes for the halfpipe. Coaches, relying on visual cues and experience, may provide more objective feedback compared to athletes, whose self-assessments can be biased. Biomechanical analysis could help standardize these cues and enhance coaching feedback.

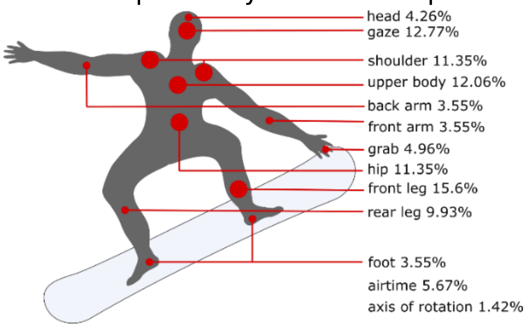


Figure 2: Localization of 13 cues based on a total of 141 instances of coaches'

CONCLUSION: Coaches and athletes perceive movements subjectively in different ways. Integrating biomechanical analysis into coaching could further refine visual cues, enabling more evidence feedback and improving athletes' technique and safety when transitioning tricks from trampoline training to on-snow performance.

REFERENCES:

[1] Merz C, Gorges T. Olympiazyklenanalyse in den Snowboard Freestyledisziplinen 1998–2022 – Schwerpunkt Halfpipe [Olympic cycles analysis in snowboard freestyle disciplines 1998–2022 – Focused on halfpipe]. In: Sandau I, Wick J, editors. Olympiaanalyse Peking 2022: Olympiazyklusanalysen und Auswertungen der Olympischen Spiele und Paralympics Peking 2022 in ausgewählten Sportarten [Olympic analysis Beijing 2022 ; Vol. 18. Aachen: Meyer & Meyer Verlag; 2023. p. 128–140.

[2] Sands WA, Kelly B, Bogdanis G, Barker L, Donti O, McNeal JR, et al. C Comparison of bungee-aided and free-bouncing accelerations on trampoline. Sci Gymnast J 2019 ;11:279–88. https://doi.org/10.52165/sgj.11.3.279-288.

[3] Bacik B, Kurpas W, Marszałek W, Wodarski P, Sobota G, Starzyński M, et al. Movement Variability During the Flight Phase in a Single Back Sideflip (Wildcat) in Snowboarding. J Hum Kinet 2020 ;72:29–38. https://doi.org/10.2478/hukin-2019-0006.

FREESKIERS` SELF-ORGANIZED AND UNIQUE PATHWAYS TO WORLD-CLASS PERFORMANCE IN BIG AIR

Berg-Johnsen, E.[1], *Rudd, J*[1] *& Aune, T.K.* [2]

[1] Department of Teacher Education and Outdoor Studies, Norwegian School of Sport Science; [2] Department of Sport Science, Sport and Human Movement Science Research Group (SaHMS), Nord University.

Keywords: expertise, training principles, specialization, lifestyle sports, action sports.

INTRODUCTION: Development of expertise in sports is an outcome of a complex process that emerges as dynamic interactions among various sport-specific constraints [1, 2]. The present study investigates the unique pathway to skill acquisition for world-class freeskiers based on the following specific objectives: 1) How world class athletes create the idea for a new big air trick and how they design practice towards mastering the new skill, and 2), How the practice designs align with key skill acquisition principles.

METHODS: A qualitative research approach was conducted using semi-structured interviews of 8 world-class freeskiing athletes (6 men and 2 women) and two coaches from the Norwegian National Freeski team. The data was analyzed using the six phases of thematic analysis.

RESULTS/DISCUSSION: Athletes and coaches describe the process of mastering new and complex skills to be highly self-organized and individualized, involving co-creation dynamics between athletes and coaches. Athletes describe two main pathways of skill acquisition: replicating a trick done by other athletes and creating entirely new tricks. All athletes and coaches acknowledged that developing new tricks is more challenging, but also as the most prestigious and creative process. Motivations for learning new tricks varies between short-term goals of competitive success to the desire for innovation and creating unique tricks, independent of competition scores. The learning process described by athletes and coaches aligns with an ecological perspective, emphasizing individual differences and a focus on the interaction between the athlete, the environment, and the task. The athletes self-organized training design reflects key skill acquisition principles, even though athletes are not explicitly aware of these principles. Athletes and coaches describe practice activities that progressively enhance specificity and task representativeness, continually challenge their current capabilities through the training principle of overload and incorporate variability to support skill retention and minimize monotony.

CONCLUSION: The world class freeskiers describe a systematic and self-organized approach to design and practice to accomplish new and complex skills. While not explicitly aware of the underlying training principles, they inherently and extensively apply training principles such as specificity, overload, individuality, and variability in practice. The elite freeskiers` pathway to world class performance is characterized by a high level of ownership to their individual skill development, facilitated through a self-organized approach. We argue that increasing athletes and coaches' competence around the ecological dynamics of skill acquisition can further improve the quality of practice and reduce risks of injury. Freeskiers' unique and self-organized method of skill acquisition may have broader implications for a more comprehensive understanding of different pathways to world-class performance in other sports.

REFERENCES:

[1] Güllich, A. (2017). International medallists' and non-medallists' developmental sport activities–a matched-pairs analysis. *Journal of sports sciences*, *35*(23), 2281-2288.
[2] Phillips, E., Davids, K., Renshaw, I., & Portus, M. (2010). Expert performance in sport and the dynamics of talent development. *Sports medicine*, *40*(4), 271-283.

DEVELOPMENT OF THE PERFORMANCE STRUCTURE MODEL IN SNOWBOARD SLOPSTYLE AND BIGAIR

Hiroki Ozaki[1], *Yuki Inaba*[1], *Arata Kimura*[2], *Yusuke Yamamoto*[3]
[1]Department of Sport Science and Research, Japan Institute of Sport Sciences, Kita-ku, Tokyo
[2]Department of Sports and Health Studies, Hosei University, Machida, Tokyo
[3]Digital Promotion Office, Japan Sport Council, Kita-ku, Tokyo

Keywords: Performance structure model, Deterministic, Slopestyle, Big air

INTRODUCTION: The performance structure model (PSM) is one of the better tools when considering the structure of sport. The model aims to provide a comprehensive framework for evaluating and supporting athletes, ensuring they receive the necessary training and resources to excel in competitive environments. We therefore built a PSM for Snowboard Slopestyle Big Air (SSBA) before providing scientific support to the Japanese National SSBA Team.

METHODS: It is important for PSM that the upper elements be fully explained by the lower elements and that they be expressed in physical quantities whenever possible [1]. We therefore determined the higher-level elements based on the SSBA competition rules; since SSBA is a scoring competition, the highest-level element is Scale. Next, each element listed in the competition rules was logically decomposed until a measurable physical quantity was obtained. When building the model, scientists not only examined the model logically, but also sought input from coaches and athletes to ensure that there were no omissions in the elements.

RESULTS: Figure 1 shows the PSM for the SSBA we constructed (Fig.1). The elements in bold are those listed in the rulebook. The elements at the bottom are those that can be measured by sensors and fitness measurements. The model revealed the relationships among the elements.

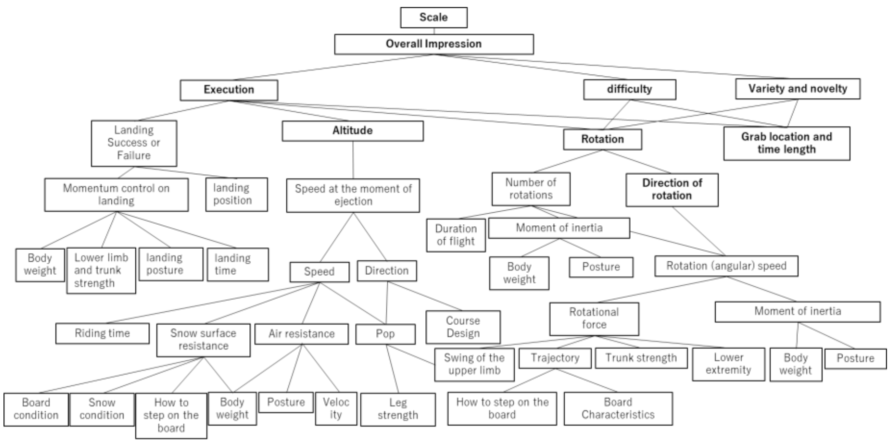


Fig.1 The performance structure model in SSBA

DISCUSSION/CONCLUSION: PSM allows athletes, coaches, and scientists who want to make changes in technique or fitness to begin training with an understanding of the expected benefits and risks before the training. It also allows us to mechanically understand what elements to change next if the training is not effective. For example, athletes often wish to gain or lose weight. In the PSM, however, "body weight" is located in four places, and the advantages and disadvantages of changing weight vary depending on the location. In conclusion, this PSM allows us to consider the advantages and disadvantages of interventions before coaches and scientists initiate.

RFERENCES:

[1] Hey JG and Reid JG. Prentice-Hall. 1982.

PERCEPTIONS OF MENTAL SKILL DEVELOPMENT IN YOUTH SNOW SPORTS ATHLETES: A QUALITATIVE INTERVIEW STUDY

Müller Philippe O [1,3], Ulrike Schwarzer [1], Dave Collins [2], Renato Frey [3], Jörg Spörri [1]

[1] Department of Orthopaedics, Balgrist University Hospital, University of Zurich, Switzerland [2] Human Performance Science Research Group, Institute for Sport, Physical Education and Health Sciences, The University of Edinburgh, Edinburgh, United Kingdom [3] Cognitive and Behavioral Decision Research, Department of Psychology, University of Zurich, Switzerland

Keywords: athlete, snow sports, mental skills, qualitative research

INTRODUCTION: To achieve sporting excellence, mental skills play a crucial role; not only in optimising performance but also in developing an athlete's personality and mental health. However, there is disagreement about the definition and implementation of long-term development strategies regarding mental skills.[1] The aim of this study was to explore current practices, barriers and opportunities related to mental skill development in youth snow sports athletes.

METHODS: In a qualitative study, 8 semi-structured in-depth interviews were conducted with international experts involved in mental skills development programmes, including coaches and sport psychologists. Inductive data analysis followed the principles of grounded theory.[2] The transcripts were analysed using the constant comparative method. Codes were organised into core categories, and the main theories emerged.

RESULTS: According to the interviewees, the organisational structure, interactions and processes play important roles in the implementation of mental skills development programmes. Clearly defined roles and responsibilities are considered crucial to the systematic mental development of athletes. Financial and human resources were mentioned as the most frequent barriers. In addition, the implementation process is often hindered by a lack of knowledge among decision makers about the benefits of mental skills development. When better interdisciplinary cooperation (e.g. teachers, coaches, parents, sports psychologists) is organised, better resources can be bundled, and mental health programmes can be put into practice.

DISCUSSION/CONCLUSION: To reflect the long-term nature of a healthy career, mental skills programmes should be embedded in an organisation's policies. This will also clarify responsibilities, and (ideally top-down) actions can be derived. A central aspect of this is the systematic training of coaches to provide knowledge about healthy and successful mental development and the use of mental interventions.

REFERENCES:

[1] Till, K. et al. (2022). Optimising long-term athletic development: An investigation of practitioners' knowledge, adherence, practices and challenges. PLOS ONE, 17(1)

[2] Glaser, B., & Strauss, A. (2017). Discovery of grounded theory: Strategies for qualitative research.

MECHANICAL ENERGY AND KINEMATICS OF DIAGONAL STRIDE TECHNIQUE IN WORLD CUP SKI MOUNTAINEERING RACES

Renzo Pozzo[1,2], Andrea Besseghini[2], Antonio Canclini[3], Guido Baroni[3], Stefan Lindinger[2], Magdalena Karczewska-Lindinger[2], Arrigo Canclini[2]

[1] DMED, University of Medicine, Udine, Italy [2] LABIS, Liceo Bormio, Italy [3] Polytechnic, Milano, Italy

Keywords: mechanical energy, diagonal stride, ski mountaineering

INTRODUCTION: In the last decade, SKIMO skiers improved their technical and physiological performances in all kinds of races. Due to the complex multiparametric environment conditions and the relatively recent development of the discipline, there is a lack of specific studies, especially under race conditions [4]. On the other hand, technique and physiological analysis comparing normal race and treadmill conditions have been undertaken [1-5]. The purpose of this study is to investigate the kinematics and the energy patterns of elite SKIMO skiers during high-level competitions such as Sprint World Cup races.

METHODS: Data collection was performed in 2016, 2017 and 2022 during 3 World Cup sprint qualifications. For each race, a minimum of 5-10 top male and female skiers were analyzed by standard 3D kinematic analysis (CCD-Camera 50Hz) on an uphill section (21°) where the athletes performed Diagonal Stride (DS). Mechanical energy fluctuation was calculated using the same approach presented early where R+ and R(t)cyc indicate the energy recovery indices for only the positive variations or the absolute values of positive and negative energy fluctuations respectively. R(t)cyc is computed by the sum of poling (R(t)pol) and swing phases (R(t)swi) [5].

RESULTS/DISCUSSION: Mean value averaged on 4 movement cycles were calculated. For males, CoG velocity was similar but poling time differs with higher values in the 2016 race. The vertical CoG displacement was higher in 2022 (Tab. 1). The R+ values were consistent (16,12 % vs 15,54%) in both races but differences are noted for R(t)cyc (15,61 % vs 21,14%) and this is mostly accounted for by the amount of the poling phase (R(t)pol Tab.1). Females show lower CoG velocity and higher R+ and Rcyc values (39,37% and 30,71%) respectively. Some linear and nonlinear relationships were found between the R(t) indices and kinematic parameters.

Table 1. Kinematic and energy recovery variables in the three WC races considered

Variables		2022 MALES_22	2016 MALES_16	2022 FEMALES_22
avg Vel	[m/s]	2,00 ± 0,08	1,99 ± 0,05	1,36 ± 0,08
CL	[m]	1,71 ± 0,12	1,80 ± 0,22	1,36 ± 0,05
CT	[s]	0,85 ± 0,05	0,91 ± 0,10	1,00 ± 0,06
Time Poling_CT	[%]	52,24 ± 6,09	61,37 ± 2,07	57,87 ± 5,08
DispY_CoG	[cm]	9,26 ± 2,16	6,69 ± 2,77	6,10 ± 1,44
Elbow_PP	[deg]	78,26 ± 10,61	93,50 ± 28,63	79,33 ± 9,45
Elbow_PO	[deg]	145,06 ± 10,86	141,20 ± 24,94	134,74 ± 8,94
Elbow_min	[deg]	73,98 ± 9,20	74,58 ± 6,59	72,22 ± 11,12
Trunk_PP	[deg]	55,39 ± 3,07	50,23 ± 3,71	59,32 ± 5,23
Trunk_PO	[deg]	50,69 ± 5,09	48,47 ± 4,33	56,99 ± 6,33
Should._PP	[deg]	62,82 ± 6,80	56,20 ± 11,89	63,05 ± 10,79
Should._PO	[deg]	31,31 ± 5,97	38,05 ± 4,95	32,85 ± 3,96
Pole_PP	[deg]	46,78 ± 3,64	45,30 ± 3,12	46,54 ± 4,92
Pole_PO	[deg]	59,97 ± 4,73	58,85 ± 7,59	58,18 ± 4,08
R+	[%]	16,12 ± 13,10	15,54 ± 5,53	39,37 ± 9,65
R(t)cyc	[%]	15,61 ± 6,64	21,14 ± 7,34	30,71 ± 9,09
R(t)pol	[%]	6,57 ± 4,98	13,27 ± 6,81	18,78 ± 7,22
R(t)swi	[%]	9,04 ± 2,85	7,87 ± 4,54	11,93 ± 5,65

CONCLUSION: Significant changes in the time structure occur during the years and this is due mostly to a reduction of the poling time decreasing from 61% to 53% of the entire cycle time (CT). Comparing these results with those obtained for CCS specialists in a WC-race 2009 (8° inclination), CCS show significant differences for the CoG kinematics with higher values of avg_Vel, CL, CT and DispY (45%, 55%, 18% and 52% respectively) as well as for R+, R(t)cycl, R(t)pol and R(t)swi (51%, 44%, 24% and 53% respectively). Relationships between CL, CT and the energy recovery indices are presented.

REFERENCES:

[1] Canclini A et al., 2019. Proc. ICSS VIII
[2] Haselbacher,M et al., 2014. Wild. En. Med.
[3] Pozzo R et al., 2016. Proc. ICSNS III
[4] Bortolan L et al., 2021. Frontiers. in Physio
[5] Canclini A et al., 2021. J Science Sport Exerc

ADVANCING SKI MOUNTAINEERING GAIT ANALYSIS: MEASURING STRIDE FREQUENCY AND CONTACT TIME ON A TREADMILL WITH ACCELEROMETERS

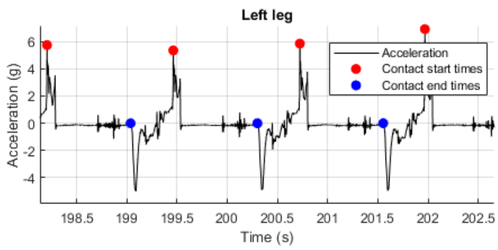
Majerič Matej[1], Erazem Černe Pezdir[2], Nina Verdel[1], Rauter Samo[1], Daniel Svenšek[2], Supej, Matej[1]*

[1] Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia
[2] Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia

Keywords: inertial sensors; IMU; movement analysis; real time measurement; SkiMo;

INTRODUCTION. Ski mountaineering (SkiMo) success in uphill segments depends on efficient push-offs of legs and poles with leg movements characterized by a complex alternation between push-off and glide phases [1]. The aim was to advance analysis by developing an algorithm to measure stride frequency and contact time on a treadmill using accelerometers.

METHODS. The pilot study involved a well-trained recreational ski mountaineer, formerly an elite alpine skier. Uphill walking was performed on a Rodby treadmill at two vertical speeds: 680 and 1008 vm/h. Two Dytran accelerometers were mounted on the skis and connected to a Dewesoft Dewe-43 analog-to-digital converter while simultaneously recorded using a DS-CAM-1100m high-speed camera. Custom algorithms shown in the figure were developed in Matlab to measure stride frequency and contact time based on horizontal acceleration data. The algorithm's accuracy was validated through high-speed video analysis by an expert in motion analysis and SkiMo, using 200 strides from both the left and right legs.



RESULTS. During uphill walking at 680 vm/h, the stride frequencies were 0.77 ± 0.018 Hz and 0.77 ± 0.011 Hz, with contact times of 0.86 ± 0.026 s and 0.85 ± 0.019 s for the left and right leg, respectively. This resulted in negligible differences in stride frequencies between the two systems (left: -0.00 ± 0.021 Hz, right: 0.00 ± 0.022 Hz), while contact times using a camera were shorter (left: -0.04 ± 0.030 s, right: -0.02 ± 0.030 s, average: -3.7%). At 1008 vm/h, the stride frequencies were 0.84 ± 0.017 Hz and 0.84 ± 0.027 Hz, with contact times of 0.76 ± 0.026 s, 0.76 ± 0.023 s, and 0.77 ± 0.028 s for the left and right leg, respectively. This also resulted in negligible stride frequency differences between the two systems (left: -0.00 ± 0.018 Hz, right: 0.00 ± 0.027 Hz) and shorter contact times using a camera (left: -0.02 ± 0.025 s, right: -0.03 ± 0.035 s, average: -2.8%).

DISCUSSION AND CONCLUSIONS. The developed algorithm reliably assessed biomechanical characteristics for ski mountaineering with negligible differences in stride frequency and slightly longer contact times compared to cameras on a treadmill, and it is expected to perform similarly on snow due to the comparable movement patterns [2]. However, increased variability, such as differing snow conditions or turns, may affect its performance.

REFERENCES.

[1] Bortolan et al. 2021, Front Physiol;
[2] Fasel et al. 2016, J Biomech

Comparative kinematic analysis of ski-mountaineering boots reveals performance-influencing joint mechanics

Michele Mattivi[1,2], Aldo Savoldelli[1,3], Martino Marchetti[4], Isacco Costa[1], Lorenzo Bortolan1,5

[1] CeRiSM (Research Center Sport Mountain and Health), University of Verona and Trento, Rovereto, Italy,
[2] Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Italy,
[3] CIBIO, University of Trento, Trento, Italy
[4] Oberalp Group, Bolzano, Italy
[5] Department of Engineering for Innovation Medicine, University of Verona, Verona, Italy,

Keywords: Ski Mountaineering, ski boots, biomechanics, performance, Olympics

INTRODUCTION: In the context of ski mountaineering's evolution as an Olympic discipline, especially ahead of the Milano-Cortina 2026 Winter Games, optimizing equipment for performance has gained prominence [1]. Central to this optimization is the ski boot, a critical component that directly influences an athlete's efficiency and mobility during both ascent and descent. The weight and design of ski mountaineering boots play pivotal roles in determining overall performance, as even minor variations can significantly affect the energy cost and mechanical workload of the skier [2]. These characteristics become particularly relevant in the high-intensity context of competitive races, where every detail can impact results.

METHODS: Seven athletes (VO2max: 63.8 ml/kg/min) competing at the national level participated in the study. Each athlete completed two time-to-exhaustion tests, separated by a recovery period of two hours to minimize fatigue carryover. The order in which the ski boots (PG: Pierre Gignoux Race Pro; R: Dynafit, Rabbit) were tested was randomized to control for potential sequence effects. Both tests were conducted at a constant speed of 8.5 km/h on a 25% incline to simulate sprint competitive conditions. During each trial, kinematic data of the lower limbs were recorded using a motion capture system. The collected data were analyzed using a paired t-test to compare the results between the two boot conditions.

RESULTS: No significant differences were found in the duration of performance between the two boot conditions, even when grouping the data by first and second trials. However, significant differences were observed in several kinematic parameters. Additionally, the duty cycle was found to be greater for the R boot, indicating a longer stance phase relative to the total stride cycle.

	PG	R	p	E.S.
Foot incl. on (°)	164.7±0.8	168.1±0.8	<0.01	4.2
Ankle angle min (°)	73.6±1.5	69.5±2.2	<0.01	2.0
Ankle range (°)	57.3±5	60.2±6.2	0.04	0.5
Tibia incl off (°)	48.3±3.4	46.4±3.3	<0.01	0.5
Thigh incl. off (°)	87.8±4.2	89±4.7	0.04	0.2

DISCUSSION/CONCLUSION: The absence of significant differences in performance duration suggests that both boot types support comparable endurance under test conditions. However, the observed kinematic variations indicate that boot design influences joint mechanics during skiing. The greater ankle range of motion and duty cycle seen with the R boot may enhance adaptability and energy transfer during the stance phase, whereas the increased knee range with the PG boot may indicate differing load distribution strategies. These findings highlight the importance of tailoring ski mountaineering boots to the specific biomechanical needs of athletes, potentially impacting performance in diverse race formats.

REFERENCES:

Bortolan L. et al., 2023. Applied Sciences
Bortolan L. et al., 2024. Sport Sciences for Health

SHORT OR LONG? ANALYZING THE IMPACT OF SKI POLE LENGTH ON ELITE SKI MOUNTAINEERS' PERFORMANCE

Nina Verdel[1], Lorenzo Bortolan[2], Hans-Christer Holmberg[3], Barbara Pellegrini[2], Matej Supej[1]

[1] Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia [2] CeRiSM, Sport Mountain and Health Research Center, University of Verona, Rovereto, Italy, [3] Department of Health Sciences, Luleå University of Technology, Luleå, Sweden

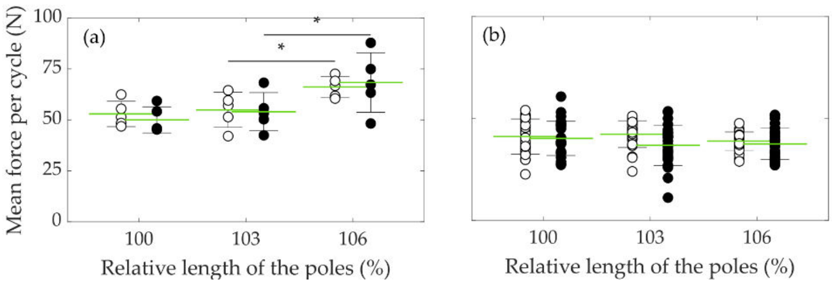
Keywords: GNSS, pole force

INTRODUCTION: Ski mountaineering (SkiMo) is a rapidly growing winter sport, and the 2026 Winter Olympics will feature ski mountaineering for the first time [1]. Olympics competitions will include men's and women's sprint races, as well as a mixed relay event. Sprint races in ski mountaineering consist of short courses with ascents of less than 80 meters, lasting between 180 and 210 seconds [1]. The first round comprises an individual qualification, with athletes starting every 20 seconds. After qualifying, athletes compete against one another in heats of six. The race start is similar to that of cross-country skiing. Studies have shown that cross-country skiers can benefit from using longer poles [2]; therefore, the aim of this study is to test this approach for ski mountaineering athletes.

METHODS: Five elite ski mountaineers participated in the study. Measurements were conducted on a ski slope with a course length and elevation similar to SkiMo sprint races. Each participant ascended the slope three times, with the pole length changed for each ascent: participant's preferred length, 103%, and 106% of the preferred length. The order of pole lengths was randomized. For each ascent, the following data were collected: ascent time, athlete's heart rate (Polar H10), c) athlete's position via Global Navigation Satellite System (Ublox), and forces in the poles (Deltatech Italy).

RESULTS/DISCUSSION: The results presented are for a single female athlete. The pole lengths order was 100%, 103%, and 106% of the preferred length. The ascent times were 2:21.97, 2:22.55, and 2:20.66. The maximum and average heart rates were 172, 172, 173 and 163, 163, 166, respectively.

Figure shows the mean force calculated for the initial 5 cycles on the flat part of the course, and for the final 25 cycles at the end of the uphill.



However, on the last hilly part of the ascent, there was no difference in the mean force between different poles. In addition, on the flat part, the average speed of the athlete was 13.1, 13.8, and 14.3 km/h, and on the last ascent part, it was 6.1, 5.9, and 6.2 km/h, respectively for 100%, 103%, and 106% length of the poles.

CONCLUSION: In conclusion, preliminary analysis seems to demonstrate that the athlete tested here benefited from using longer ski poles, particularly on the flat part of the race. This finding highlights the potential value of systematically testing each elite athlete to determine their optimal pole length, which could enhance performance outcomes.

REFERENCES:

[1] Bortolan L. et al., 2021. Front. Physiol.
[2] Torvik, P- Ø et al., 2021, Front. Sports Act. Living

EVOLUTION OF BIOMECHANICAL MEASUREMENT IN ALPINE SKIING: THE OUTDOOR LABORATORY BEYOND MILANO CORTINA 2026

Matej Supej[1]

[1] Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia

Keywords: kinematics, inertial motion capture, IMU, Global Navigation Satellite System, GPS, force

INTRODUCTION: Alpine skiing is a sport that presents significant physical, technical, and tactical complexities and challenges. The intricacies of adapting turning techniques to diverse terrain, slope configurations, gate setups, and snow conditions necessitate a thorough biomechanical analysis of the factors that influence elite performance and safety [1]. Historically, researchers have examined various kinematic and kinetic parameters such as time, trajectory, turning radius, speed, ground reaction forces, aerodynamic drag, ski-snow friction, energy dissipation, and joint torques as well as their interactions with turning techniques, tactics, and equipment. In this presentation, I will focus on the evolution of the most widely utilized biomechanical measurement techniques in alpine skiing, with an emphasis on what we can anticipate beyond the Milano-Cortina Olympic Games in 2026.

DISCUSSION: The foundations of modern biomechanics of human locomotion were laid in Göttingen by the Weber brothers in the early 19th century. While progress was initially slow by today's standards, Eadweard Muybridge's development of photogrammetry before the end of the 19th century provided the groundwork for modern kinematics. In alpine skiing, 3D kinematic analysis began in the late 1970s. Given the sport's complexity, it is unsurprising that innovations in kinematic and kinetic measurements from other fields were rapidly adopted in skiing research. Techniques such as pan-tilt-zoom cameras [2], and infrared cameras with markers [3] quickly became staples of ski biomechanics. Due to the spatial limitations of video-based measurements, high-resolution GNSS systems were subsequently introduced, later enhanced with inertial motion capture suits [4]. These wearable devices have evolved to become smaller, lighter, and more efficient. Recently, markerless motion capture systems powered by artificial intelligence have gained traction [5], offering not only advanced motion capture capabilities but also data processing potential [6]. Since kinetics is crucial for understanding motion, measuring ground reaction forces has become a cornerstone of biomechanical research [7]. This involves assessing forces in three dimensions, determining the centre of pressure, and miniaturizing systems to make them lighter and more portable.

CONCLUSION: Considering the latest advancements in sports technology, including stretchable electronics for smart patches [8], AI-based 3D motion capture and data analysis tools, two distinct pathways for "outdoor laboratories" emerge. On one hand, ultra-light, thin, compliant inertial mocap; on the other, AI-driven video-based kinematics, both supported by AI-automated data processing. Combined with lightweight and unobtrusive GRF measurement systems, these technologies will enable seamless musculoskeletal modelling, pushing the boundaries of biomechanical research in the field beyond the Milano-Cortina 2026.

REFERENCES:
[1] Supej et al. 2019, Front Physiol
[2] Nachbauer et al., 1996, J App Biomech
[3] Spörri et al. 2016, PLoS One
[4] Supej 2010, J Sport Sci
[5] Ostrek et al. 2019, Sensors
[6] Nemec et al. 2014, Sensors
[7] Hull et al. 1978, J Dyn Sys Meas Control
[8] Verdel et al. 2023, Front Physiol

3D SKI BOOT DEFORMATION FROM DISTRIBUTED IMUS

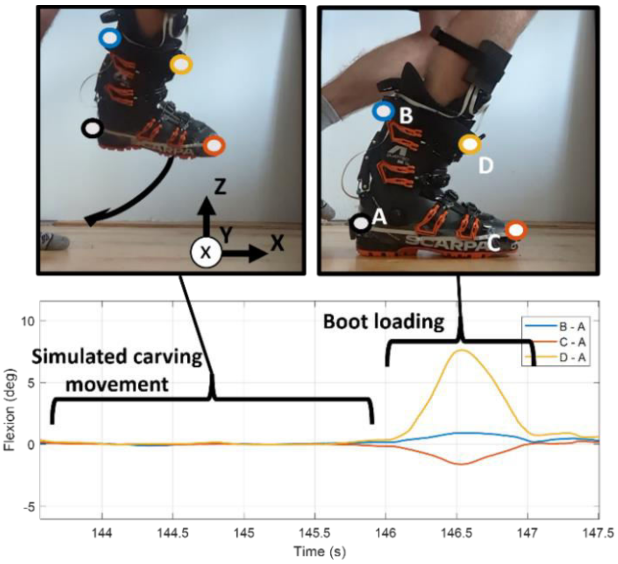
Samuel Dallain[1], Alexis Lussier Desbiens*[1]*

[1] Department of Mechanical Engineering, University of Sherbrooke, Sherbrooke, Canada

Keywords: ski boot, IMU, deformation, torsion, flexion

INTRODUCTION: Ski boots are an important piece of equipment for alpine skiing: they play a vital role both in protecting the skier from injuries and transmitting loads to the ski. Ski boots exhibit complex nonlinear material deformation under load [1]. Measuring those deformations in-run could provide valuable information for manufacturers (e.g. optimizing mass) and for users (e.g. choosing an appropriately stiff boot). Various methods have already been tested: angular potentiometers [2], electrogoniometers [2] and strain gauges [3]. A new method is proposed which uses distributed IMUs. This could provide a less intrusive, more accurate, complete 3D deformation of ski boot at multiple locations even through the presence of mechanical joints, large shell deformations and liner compression.

METHODS: A Scarpa Quattro SL boot was equipped with four IMUs (A, B, C, D) positioned as shown in the figure. The 3D angular velocity was recorded at 1000Hz and stored on a datalogger strapped to the user's tibia. A custom post-processing algorithm obtains 3D orientation for each point and calculates the difference in orientation for each point with regards to IMU A, chosen as a boot-fixed reference point. This difference corresponds to the angular deformation for each point and is de-drifted using a new method as to correct for IMU noise and other errors. A simple preliminary test was performed indoors. The subject alternated between simulated movements (swinging the boot once from side to side) and loading the boot with his full weight.



RESULTS/DISCUSSION:
Flexion (deformation around Y axis) is plotted for 3 measurement points (B, C, D), with reference to A. Deformation around X (torsion) and Z axis are also available, but not shown here. During the off ground simulated carving movement, flexion remained close to zero, as expected. Stability of the deformation during this moment shows that the signal was successfully de-drifted. During loading, flexion of the front of the cuff (D-A) was the greatest (7deg), flexion at the back of the cuff (B-A) was small and flexion of the base of the boot (C-A) was in the negative direction. These measurements align with expected boot behavior, supporting the validity of our system for capturing realistic deformations.

CONCLUSION: A novel IMU-based ski boot deformation system was developed. This system incorporates inertial navigation and a custom de-drifting technique to calculate 3D angular deformation of multiple points of the boot. Preliminary results suggest the system's potential for accurate deformation measurements, and further testing in real skiing conditions will validate its practical application.

REFERENCES:
[1] Nicola Petrone et al., 2013, Sports Eng 16.
[2] Giuseppe Zullo et al., 2023, MDPI Sensors.
[3] Stefano Corazza et al., 2005, J Sports Sci Med.

RELIABILITY OF SYSTEMS FOR SKIER BIOMECHANICS ANALYSIS: FROM LAB TESTING TO ON-SLOPE PERFORMANCE

Giorgia Celeste Cuniberti * [1,2], *Isacco Costa* [1], *Lorenzo Bortolan* [1,3]
[1] CeRiSM, University of Verona and University of Trento, Italy; [2] Department of Neurosciences, Biomedicine, and Movement Sciences, University of Verona, Italy, [3] Department of Engineering of Innovation in Medicine, University of Verona, Italy.

Keywords: alpine skiing, ski boot, kinematic testing, motion capture

INTRODUCTION: Alpine skiing is a popular sport at both amateur and competitive levels, characterized by complex biomechanics. However, research on skiing biomechanics is limited due to the challenges of replicating real-world conditions in controlled environments and conducting on-field studies where conditions are variable. Technological advancements have made it easier to use equipment even in difficult environments. In movement analysis, motion capture (MoCap) systems provide valuable data for training and injury prevention, with passive marker-based systems being the gold standard in laboratories. However, these systems are less effective outdoors due to sunlight and snow reflections[1], while inertial MoCap systems are more practical for outdoor conditions[2]. This study compares various measurement systems for assessing skier biomechanics, focusing on their effectiveness in capturing key movement parameters and forces in both simulated and real on-slope conditions.

METHODS: Six subjects performed nine trials, each lasting 20 seconds, during which they executed flexion-extension movements of the lower limbs to simulate the technical gesture involved in skiing. The trials were conducted on an inertial system (YoYo, Hance, Sweden) equipped with ski bindings, and the subjects were fitted with an X-sens system (Movella) to derive the ankle flexion angle. Additionally, markers were placed on the ski boots and the tibial tuberosity of the subjects, which were recorded by six cameras of the MoCap system (Qualisys) to obtain a reference angular value. The forces exerted by the subjects were measured using two methods: four load cells (Fyearfly 200kg) mounted between the ski bindings and the inertial system, two for each side, one in the front and the other in the rear of the binding, and sensorized insoles (Pedar Loadsol-mlp) placed inside the ski boots.

RESULTS/DISCUSSION: The comparison between the two motion capture systems showed excellent results in detecting ankle angle variation. The values provided by both systems, a significant correlation ($p < .001$) and a strong linear relationship ($R^2 = 0.91$). The analysis of the force data revealed that the load cells measured higher force values than the insoles (mean value 709.5 ± 239.8 N vs. 401.6 ± 135.8 N, respectively). This difference may be due to the placement of the load cells under the bindings, while the insoles were located inside the ski boots. We can hypothesize that the force detected by the load cells is the sum of what is detected by the insoles plus the load transmitted from the leg through the ski boot. However, the correlation between the two data sets was statistically significant ($p < .001$). Notably, a moderately strong quadratic fit ($R^2 = 0.67$) implies that there is a non-linear relationship that captures the variance in the data, further supporting the relationship among the observed data.

CONCLUSION: The study demonstrates that both motion capture systems effectively detect ankle angle variations with a strong correlation. While the load cells measure higher forces, the significant correlation with insole data suggests that insoles reproduce approximately 70% of the load cell measurements. Therefore, they can be used for measurements during on-slope skiing, but the results should be analyzed with caution, as they do not precisely reflect the forces exerted on the skis.

REFERENCES:
[1] Nedergaard, N.J. et al, 2014 Sports Eng
[2] Supej, M. et al, 2021 J. of Sci. In Sport and Exercise

BEYOND THE CARVING-SKIDDING DICHOTOMY: SENSOR-ASSISTED MEASUREMENT OF ANGLE OF ATTACK IN SKIING

*Christoph Thorwartl * [1], Sebastian Schütz [2], Helmut Holzer [3], Bernd Resch [2,4]*

[1] Salzburg Research Forschungsgesellschaft m.b.H., Austria [2] Department of Geoinformatics, University of Salzburg, Austria [3] Atomic Austria GmbH, Altenmarkt-Zauchensee, Austria [4] Center for Geographic Analysis, Harvard University, Cambridge, MA, USA

Keywords: alpine skiing, angle of attack, GNSS, IMU, ski trajectory

INTRODUCTION: A carving turn is defined by the ski experiencing minimal to no lateral movement relative to its path. Divergence between the ski's orientation vector (E) and the resultant velocity vector (v), known as the angle of attack (AoA), results in skidding. Reid et al. (2020) investigated the AoA in the field using a videographic method, but this approach was laborious [1]. Up to now, only Schütz et al. (2024) have reported a sensor-based solution, but it was tested solely in the lab, without field data [2]. Therefore, this study aims to evaluate a sensor-based solution for detecting AoA in the field and distinguishing between carving, parallel ski steering, and transitions.

METHODS: Four IMUs (Xsens DOT) and a GNSS (Xsens, MTi-680G) were equipped to the ski (Atomic Redster G7, length: 1.82 m, radius: 17.3 m) with the antenna of the GNSS sensor placed directly on top of the GNSS sensor. The participant carried a backpack with a laptop to connect to the GNSS and performed 20 turns of each of the following: (i) carving, (ii) parallel ski steering, and (iii) transitions from parallel ski steering to carving. To address distortions in v data during skiing, a three-step filtering process was applied separately to each dimension: (i) Kalman smoothing, (ii) Hampel filtering for outlier removal, and (iii) Butterworth low-pass filtering. The AoA was subsequently calculated using the procedure outlined in previous research [2]. The runs were divided into individual turns using gyroscope-based turn detection in accordance with Martinez et al. (2019) [3]. The right turns (instrumented outer ski) were time-normalized, and the mean AoA ± standard error (SE) was calculated for each technique.

RESULTS/DISCUSSION: Figure 1 shows the mean AoA ± SE for all techniques. The results indicate that carving has the lowest mean AoA of 6.26°, while parallel ski steering has the highest mean AoA of 18.80°. The peak AoA for parallel ski steering is 32.47°, and the minimum AoA for carving is 4.09°. This is in line with past research, showing that the AoA increases as skidding is introduced [1]. During the transition, the maximum AoA of 22.13° is reached at approximately 20% of the turn completion, after which it decreases. This observation aligns with the video data, which clearly shows a transition from a skidding to a carving turn. In summary, each skiing technique can be associated with a distinct progression of the AoA during a turn.

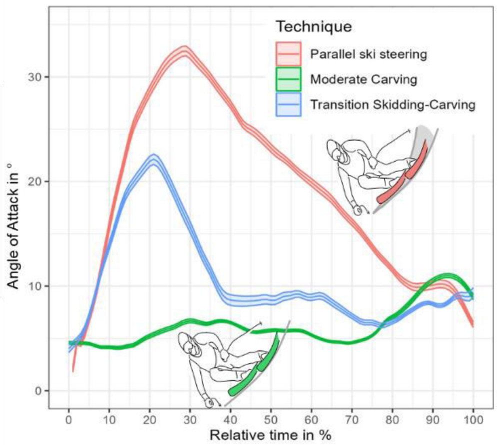


Figure 1: Mean Angle of Attack +/- standard error for different techniques.

CONCLUSION: Given that the AoA examines the definition of carving, the authors consider it crucial for monitoring and improving performance. Tracking AoA gives coaches and athletes insights to refine technique and make data-driven adjustments for better skiing proficiency.

REFERENCES:

[1] Reid, R. C. et al, 2020 Frontiers in Sports and Active Living, 2, 25.
[2] Schütz, S. et al, 2024 ISBS Proceedings Archive: Vol. 42: Iss. 1, Article 208.
[3] Martinez, A. et al, 2019 Sensors, 19(4), 902.

EDGE ANGLE ESTIMATION USING IMUS – AN IN-FIELD VALIDATION APPROACH USING AI POSE ESTIMATION

Hummel Chris 1*, *Andreas Huber 2*, *Peter Spitzenpfeil* [1], *Karlheinz Waibel* [3]

[1] Applied Sport Science, Technical University of Munich, Munich, Germany [2] Olympiastützpunkt Bayern, Munich, Germany [3] German Ski Federation, Planegg, Germany

Keywords: alpine skiing, edge angle estimation, IMU, AI pose estimation

INTRODUCTION:

Ski-snow interaction is the essential component of alpine skiing. A skier changes his trajectory and speed by manipulating the orientation and loading pattern, generating a reaction force from the snow surface which results in a change of direction (Reid et al., 2020). Using IMUs to determine, edging angles allows to measure the ski orientation throughout a complete run, but a concern is sensor offset, sensor drift and saturation leading to wrong estimations of the ski orientation. In simulating skiing with similar angular velocity and cycle frequencies we were able to estimate peak edge angles within ±1.96° (95% LoA) of a reference system using IMUs (Hummel et al., 2024) applying the Madgwick filter (Madgewick et al., 2011). In this study, we want to validate not just peak angles, but also investigate curve progression in an on-snow experiment.

METHODS:

Two IMUs (1000 Hz, 6-DOF, 16-bit, ± 2000°/s, ± 16 g) are mounted in two different setups:

1) To the back of both ski boots.
2) To the top of the left Ski and to the back of the left ski boot.

Before IMUs are mounted, axes are adjusted and the accelerometer and gGyroscope are calibrated. Three trials each are performed by former ski racers and coaches (n = 3). Every trial starts with a five-second zero-movement-phase to remove gyroscope offset and retrieve the initial orientation. Trials consist of a full hill run, of which the edge angle will be estimated throughout. The last section of each trial is evaluated against a 3D AI pose estimation system (Nemo, Simi Reality Motion Systems GmbH ©, Unterschleißheim, Germany). Calf segment orientation is compared with regards to angle progression and peak angle against the estimation of the IMUs for setup 1. Further, the deviation between ski and boot orientation is evaluated with setup 2. To assess the overall quality of the AI System's calibration a differential GPS is added to the ski and the 3D speed is compared between both systems.

RESULTS/DISCUSSION:

Pilot tests and the previous experiments on snow suggest plausible results, where no drift or saturation was detected. The accuracy and precision of the angels are yet to be investigated and results will be presented at the conference.

CONCLUSION:

Overall, the Madgwick filter is a promising approach to measure accurate edging angels for alpine skiing. The combination with pressure insoles and ski position is subject of further research to determine reaction forces and therefore, effects on change in the ski´s trajectory.

REFERENCES:

[1] Reid, R. et al., 2020. Front Sports Act Living
[2] Hummel, C et al., 2024 Current Issues in Sport Science
[3] Madgwick, S er al, 2011 IEEE International Conference on Rehabilitation Robotics

NEUROMUSCULAR ADAPTATIONS TO STRENGTH TRAINING

Marco Narici

VIBRATION-OPTIMIZED DESIGN TO IMPROVE SAFETY-RELATED PERFORMANCE

Valentin Wohlgut[1], Veit Senner[1], Patrick Carqueville[1], Matthias Ellerböck[1], Gabriel Girardini[1]*

[1] Associate Professorship of Sport Equipment and Sport Materials, Department of Mechanical Engineering, School of Engineering and Design, Technical University of Munich, Germany

Keywords: vibration, damping, ski, ice axe

INTRODUCTION: Vibration damping of sports equipment is nothing new. Over 45 years ago, the company Georg Fritzmeier GmbH & Co. KG, Großhelfendorf, Germany, presented the "Duo Ski". With the help of interchangeable weights - attached to the tip and tail of the ski - the vibration frequencies were adjusted [1]. Vibrations affect edge contact with the snow and, therefore, also the skier's control and safety [2]. Nowadays, the vibration characteristics of skis are influenced by a combination of materials with different internal damping. We use two essential pieces of ski mountaineering equipment, the ski and also the ice axe, to show how much vibrations can be influenced by material damping and weight adjustment to improve safety-related performance. While in skiing, the vibration is primarily induced by uneven ground, with an ice axe, the vibration is actively triggered by a strike from the athlete.

METHODS: The skis and ice axes measurements were divided into indoor mechanical vibration tests and/or outdoor subject tests with acceleration sensors. Standardized ski cross-sections were laminated with varying materials (glass fiber, carbon fiber, flax fiber, rubber, and Titanal) and fiber orientation for the mechanical vibration tests. In addition, using a vibration damper with varying mass at the tip of the ski is also considered. The cross-sections are clamped on one side and excited to vibrate freely by a single deflection. Two ice axe variants are analyzed: a self-developed prototype with a carbon-rubber mixt shaft versus a conventional ice axe. The ice axes are clamped on one side and stimulated to swing by a strike. 200g acceleration sensors are mounted on the skis and ice axes for the subject tests. The average accelerations and vibration frequencies are observed.

RESULTS/DISCUSSION: A ski layer structure with pure carbon fibers has the lowest damping, followed by glass fiber and flax fiber. By using a rubber layer, the damping can be increased significantly. The outdoor tests show a similar trend, although the differences are smaller. The acceleration signals at the tip of the ski result from a superposition of numerous frequencies. Vibration absorbers with a high mass at the tip of the ski increase the inertia of the system. This can reduce vibrations. However, the driving dynamics suffer. The ice axe with a carbon-rubber mixt shaft absorbs strikes better than a conventional ice axe. The use of carbon also makes it lighter. At the same time, the rubber insert increases the impact tolerance.

CONCLUSION: Carbon-rubber combinations in particular exhibit high damping behavior with low weight. Our research has shown that inserting rubber layers over the entire surface can significantly improve the safety and performance of skis and ice axes. This finding has practical implications for the design and manufacturing of sports equipment. In the future, a partial insertion should be tested, whereby the vibration behavior can be tuned even more specifically.

REFERENCES:

[1] https://www.skitalk.com/attachments/skiing-oct-1977-fritzmeier-pugski-dave-petersen-jpg.49385/, 15.10.2024

[2] Foss, G. C.; Glenne, B. (2007). Reducing On-Snow Vibrations of Skis and Snowboards. Sound and Vibration, 22–26.

COMPLETE RECYCLING OF SKIING BY SELECTIVE DISSOLUTION IN BIO-BASED SOLVENTS WITH A FULLY CIRCULAR APPROACH

*Filippo Biagi [1], Alessandro Nanni [2], Martino Colonna * [1,2]*

[1] DICAM, University of Bologna, Bologna, Italy. [2] RE-SPORT srl Bologna, Italy.

Keywords: recycling, sustainability, skis, sport equipment

INTRODUCTION: The management of skis at the end of their usable lifespan is a critical problem since, due to the lack of technological solutions, they are all disposed in landfills or incinerators with no resource recovery, thus increasing their environmental impact. The lack of technology is due to the complex composition of skis, which consists of multi-materials (polymers, wood, metals) very difficult to be separated when assembled into the final product. We have developed a novel system based on the selective dissolution using biobased solvents of some parts (top-sheet and sidewalls) [1] and the separation using heat of the other components (ski-base, edges and wood-core) to produce new secondary raw materials to be re-used in the construction of skis.

METHODS: the entire skis, after the separation of the bindings are inserted in a stirred vessel containing ethyl acetate at 50°C. After 120 minutes the side walls are completely dissolved and the top-sheet made of a bilayer TPU/ABS film is detached. The remaining part of the ski is heated at 140°C for 5 minutes and the ski-base (made of UHMWPE) and the metal edges are separated from the ski core. The wood-core is then cut and reassembled using glues into 1 cm thick wood panels to be then cut into new parts of ski cores. The polymeric (TPU, ABS, and UHMWPE) parts are then partially or completely melted and reprocessed to prepare new parts by injection molding and sintering. Steel is recycled with standard recycling routes.

RESULTS/DISCUSSION: the recovery of the ABS parts has been over 95% with 98% purity after the evaporation of the ethyl acetate solvent. The mechanical characterization of the recovered material after injection molding has shown no decrease in mechanical properties (elongation at break and modulus) with respect to the virgin material. Similar results have been obtained for the recovered TPU of the top-sheet with no properties loss. The UHMWPE from the grinded ski-base has been re-processed by sintering with no significant loss in mechanical properties. The effect of the dissolution has shown no effect on the mechanical proprieties of the wood-core. The wood has been cut into part of even thickness and assembled into new panels from which new wood-cores of skis have been obtained.

CONCLUSION: we have demonstrated for the first time the possibility to recycle end-of-life skis with a fully circular approach to create secondary raw materials that can then be used to produce new skis and thus increase their environmental sustainability. An industrial plant for the application in large scale of the process has been designed and should be operative starting in 2026.

REFERENCES: [1] Colonna M et al 2023 IT Pat 102023000012663,

SKI PROFILE CHARACTERIZATION USING DIFFERENT METHODS

Joakim Sandberg[1], Gustav Hindér[1], Andreas Almqvist[1], Roland Larsson[1]*

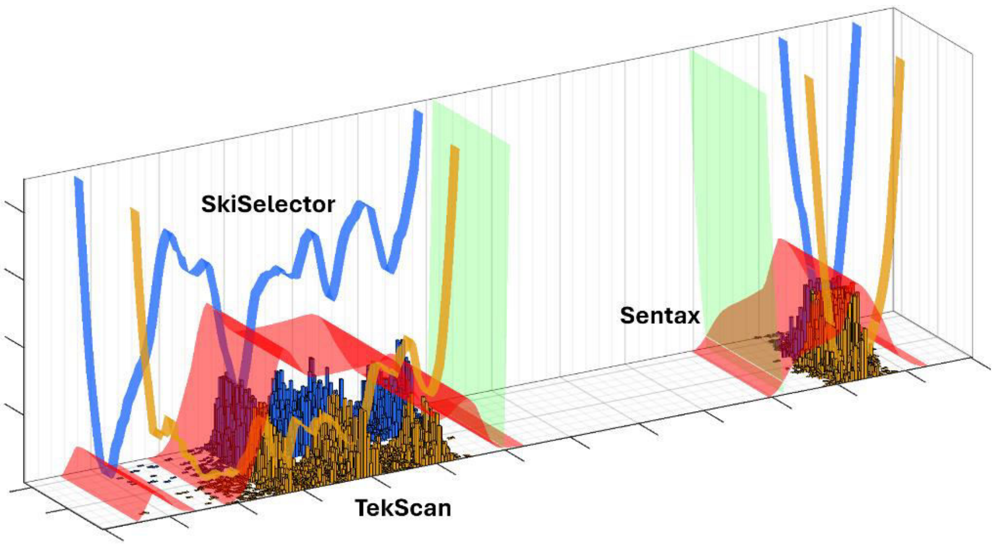
[1] Division of Machine Elements (Ski & Snow Lab), Luleå University of Technology, Sweden

Keywords: Ski Camber, Pressure Zone, Profilometer, Measurement

INTRODUCTION: One of the most important factors affecting ski performance is the ski profile, which refers to the distance between the ski base and the contacting surface (snow or ice). Today, various methods are employed by manufacturers, professional racing teams, and amateurs to determine the best skis for specific conditions, based on factors such as the length and location of the glide zones, among others. This raises an important question: How accurate are the methods used to characterize these factors?

METHODS: The ski profile was measured using three different methods: 1. SkiSelector: a profilometer with a stylus that recording the distance between the ski base and the surface it is pressed against as it slides along the ski. Both the left and right side of the ski is measured. 2. Sentax Ski Monitor: a system utilizing 56 load cells distributed along the length of the ski to quantify the pressure distribution over the glide zones, as well as 7 height gauges to measure the height within the ski camber. 3. TekScan 5630N: a pressure mapping sensor with 20 individual pressure sensitive regions per cm^2 and a total 1936 on the entire sensor, the sensor was moved along the length of the ski and individual measurements was merged to map the entire ski. A number of skis was mapped at 30/60 kg.

RESULTS/DISCUSSION: The results presented in the figure below show that the different methods can differ significantly. SkiSelector uses a 4 mm wide probe which capture a profile in a narrow section of the ski. When measuring the left and right profile (blue/yellow bands) the resulting profile look very different. Sentax seem to find larger pressure zones (red band) and narrower ski camber (green band) compared to the other two methods, this might be due to the distance between the load cells and relying on interpolation to fill in the gaps. TekScan provides a high-resolution pressure measurement, along the length and across the width of the ski and highlight the variation from left to right (blue/yellow histogram bars).



CONCLUSION: As shown the different methods can give quite different results. This could be combined with friction tests to find correlations and see which method and parameters could be used to accurately predict the best ski for a given condition.

ALPINE SKIS CATEGORIZATION AND ON-SNOW PERFORMANCE PREDICTION FROM MECHANICAL MEASUREMENTS

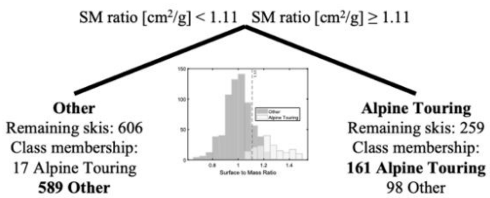
Alexis Lussier Desbiens[*1,2], Jonathan Audet*[1], Abdelghani Benghanem*[1]

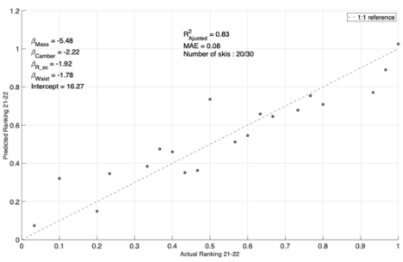
[1] Department of Mechanical Engineering, University of Sherbrooke, Sherbrooke, Canada
[2] Sooth Ski, Quebec, Canada

Keywords: alpine skis, measurements, mechanical parameters, categorization, performance, stiffnesses

INTRODUCTION: Alpine skiers are faced with too many skis to choose from during shopping. The information about the skis provided by the manufacturers is also sparse, while reviews are subject to several biases (e.g., geographical, reviewer physical characteristics and skills, preferences, fatigue) and challenges (e.g., snow types, limited testing time, reviewers agreements). This limits the reliable comparison of thousands of new skis each year. As large databases of measurements are now becoming available [1,2], it is possible to envision the automated and deterministic categorization of alpine skis, as well as the prediction of their on-snow performance.

METHODS: To achieve that goal, different categorization and performance evaluations were reversed-engineered. On one hand, the SoothSki database of alpine ski measurements was used. This database includes detailed geometry, mass and bending/torsional stiffnesses measurements of more than 5000 commercially available skis. On the other hand, the categorization of 865 skis from evo.com (e.g., Powder, All-mountain, Carving) and the rankings from Blister Gear Review were used (36 best-to-worst rankings of over 300 skis). A procedure based on Decision Trees was used to predict categories [3], while a procedure based on Elastic Net was used to predict rankings [4].





RESULTS/DISCUSSION: Results show that simple and robust rules can be found based on mechanical measurements to categorize and predict the on-snow performance of alpine skis. The rules found generally include less than three mechanical parameters and reached classification accuracy and mean absolute rank errors of respectively 97.5% and 15%. These simple rules can thus be easily analyzed to obtain a better understanding of complex on-snow performance and the reviewers' language. Furthermore, to better suit each skier's preferences, the rules can be easily fine-tuned. Finally, the automated processes could be repeated on other datasets to better represent different views (e.g., different skiing cultures).

CONCLUSION: Novel methods were developed to classify and predict on-snow performance based on mechanical properties. The rules found can be used to describe skis more easily and uniformly across brands, educate skiers, and simplify their shopping experience.

REFERENCES:

[1] www.soothski.com, accessed Oct. 13 2024.
[2] Brousseau, C. et al., 2016, *Procedia engineering*
[3] Benghanem, A., et al., 2023. *Sports Engineering*, *26*(1)
[4] Audet, J., et al., 2024. *Sports Engineering*, *(Accepted)*

A QUALITATIVE STUDY ON LEISURE INVOLVEMENT AND WELL-BEING IN SKIING. -INSIGHTS FROM QUALITATIVE RESEARCH ON SKI ENTHUSIASTS AND INSTRUCTORS-

Taro Aihara [1], Hideki Yamada [2], Hiroyuki Aihara [2], Hideo Matsumoto [3]

[1] Graduate school of Physical Education, Tokai university, Kanagawa, Japan. [2] School of Intercultural Studies, Tokai university, Hokkaido, Japan. [3] School of Physical Education, Tokai university, Kanagawa, Japan.

Keywords: Leisure Involvement, Life Satisfaction, Leisure Satisfaction, Well-being, Skiing

INTRODUCTION: Although research on the relationship between leisure involvement and well-being is increasing, there is limited focus on snow sports specifically. Existing studies tend to focus on activities like snowboarding,[1] with few targeting skiing enthusiasts. Our previous quantitative research indicated that individuals with high levels of leisure involvement, including both ski enthusiasts and instructors, report significantly higher well-being. This study aims to qualitatively examine the relationship between long-term leisure involvement in skiing and well-being by conducting semi-structured interviews with both ski enthusiasts and instructors. The findings will provide valuable insights into the long-term effects of skiing on well-being and contribute to future efforts to increase participation and promote its benefits.

METHODS: Semi-structured interviews were conducted to explore the relationship between long-term leisure involvement in skiing and well-being. Nine participants, consisting of four ski enthusiasts and five instructors were selected. All participants had comparable skiing experience, with minors excluded to ensure long-term engagement. Topics discussed included aspects of leisure involvement (attraction, centrality, social bonding), life satisfaction, and well-being, along with demographic information. The audio recordings were transcribed, and data were analyzed using the KJ method. The Trajectory Equifinality Model (TEM) was applied to examine the time-series progression of participants' skiing experiences.

RESULTS: Experiences of participants were mapped from the point of starting skiing, through essential phases, obligatory Passage Points (OPP) such as increased motivation for skiing, heightened leisure involvement, improved life satisfaction, and enhanced well-being, leading to the Equifinality Point (EFP) of continued engagement in skiing. The growth process of both ski enthusiasts and instructors was categorized into three stages: 1. Encountering skiing 2. Habitualization and integration of skiing into daily life. 3.Increased well-being through skiing.

DISCUSSION/CONCLUSION: The enthusiasm of both ski enthusiasts and instructors was generally high. Although their backgrounds and the paths leading to their continued involvement in skiing differed, some commonalities emerged. Three participants experienced temporary interruptions due to life-stage transitions, such as work-life balance issues, but all continued skiing in the long term. Participants frequently mentioned elements like nature, skill development, equipment, social connections, uniqueness, and lifelong sport as factors contributing to their high involvement in skiing. Regarding well-being, the focus of this study, participants highlighted that skiing allowed them to maintain a healthy body and mind, which enabled continued engagement in the sport. They also noted that social connections made through sking enhanced their life satisfaction and sense of happiness. Two instructors mentioned that helping others succeed contributed to their own sense of self-fulfillment and improved their well-being. However, some enthusiasts reported feelings of discomfort within the community, which poses a challenge for future research and warrants further investigation.

REFERENCES:

[1] Mirehie, M.; Gibson,M.Women`s participation in snow-sports and sense of well-being: a positive psychology approach. Journal leisure research.5,2020,51(4): p.397-41.

CURRENT STATUS OF SMALL SKI AREAS IN HOKKAIDO: MANAGEMENT BASE AND ITS USAGE

Shumpei Kurosawa * [1]

[1] Graduate School of Science and Technology, University of Tsukuba, Tsukuba, Japan

Keywords: small ski areas, public ski area, cat skiing, reopening

INTRODUCTION: Small ski areas play a crucial role in sustaining skiing culture in snow-covered towns. Past research has suggested these ski areas struggle to compete with larger ski resorts, leading them to adopt unique positioning strategies for survival [1]. However, some smaller ski areas do not primarily operate as tourist attractions. This research focuses on the factors contributing to the survival of small ski areas and their current patterns of usage in Hokkaido, Japan. In Japan, number of skiers peaked of 17.7 million in 1993, but a decreased followed the burst of the economic bubble. Many small, publicly owned ski areas were closed due to decrease in number of skiers [2]. In this study, small ski areas primarily targeting residents within Hokkaido are defined as local ski area.

METHODS: First, a comprehensive list of all ski areas in Hokkaido was compiled. Next, each ski area's operational status was categorized into three groups: in; operation, closed or suspended and reopened. Interviews were conducted with representatives from six operational ski areas and three cat ski tour operators managing reopened ski areas. The selected operational ski areas were chosen based on their geographical characteristics and size. Three cat ski tour operators in Hokkaido were subsequently interviewed.

RESULTS/DISCUSSION: In 2022, 148 ski areas were still in operation in Hokkaido, with 90 percent primarily targeting residents within Hokkaido. Most of these areas are limited to having only a rope tow or a lift. Local ski areas were in need and sustained for educational purpose in most area. 54 percent of Local ski areas were operated by education committee or tourism sector of local government. Except for the largest ski area, they struggle to promote as tourist attraction due to lack of human resource. Financially, municipality owned areas budget their operation cost with other public physical education facility. Number of those ski areas tries to profit by introducing Public Private Partnership. However, they still suffer from making a profit and ski areas decide to stop their operation. In addition, in closed or suspended ski areas, ski tour operators are renting the land and transports their clients with snowcat to provide untracked powder slopes. Operators will profit from the tour due to the reputation of powder skiing, and landowners have their forests maintained by them.

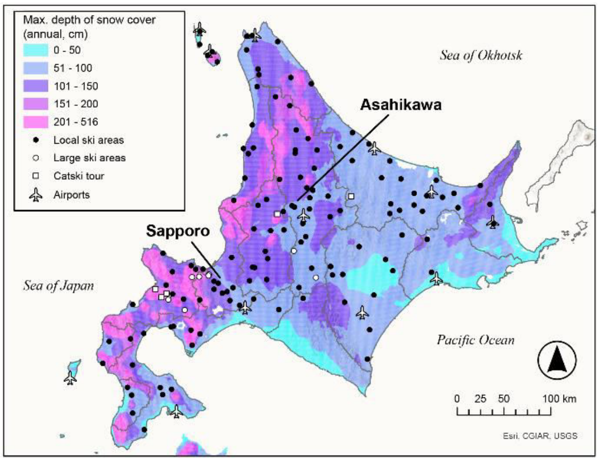


Fig. 1 Distribution of ski areas and maximum depth of snow cover in Hokkaido (2022)

CONCLUSION: Local ski areas share similar managerial problem with Europe and America. In this research, local ski areas were used for physical education class for schools. These ski areas are not considered profitable; instead, municipalities maintain them for educational purposes to preserve their skiing culture. Lastly, Ski lift is the main cost of operation, thus, cat ski operators whom using closed or suspended areas were able to profit from their strategy, by using alternate transportation and its exclusive tour package to maintain the ski area.

REFERENCES:

[1] Hetzenauer, K. et al, 2022 J. Outdoor Recreat. Tour.

[2] Kureha, M, 2014 J. Ski Sci.

DO WE LET THE CHRONIC PATIENT GO FOR SKI?

*Peter Felkai**

Debrecen University, Medical School, Internal Medicine Chair, Travel Medicine Group, Hungary

Keywords: chronic disease, accident prevention, injury prevention

INTRODUCTION:

One of the most common medical topics in skiing is the accident prevention. However, little is said about those skiers who suffer from some kind of chronic disease. In many chronic diseases, such as the epilepsy, the COPD, the diabetes etc. can be dangerous to ski, or skiing can exacerbate their existing disease, so it is advisable to discourage these patients from skiing. Unfortunately, general practitioners are often not familiar with physical and health requirements of skiing, so they cannot give proper pre-travel advice to those who go for skiing.

METHODS:

The author analyzes the most prevailing chronic diseases in point of view of ski-sport with the possibility of preventing the accidents caused by them.

CONCLUSION:

There are chronic diseases with which one cannot ski at all. In the case of other chronic diseases, if they are properly maintained and the patient's status is in balance, sports are allowed. However, even then, the patient must be adequately prepared for signs of expected illness, and for self-medication. If necessary, the consulting doctor can adjust the medication according to the circumstances.

REFERENCES:

[1] Felkai P. The ski camp doctor's role in the the prevention of winter sport accidents. Orv Hetil. 2007 Aug 26;148(34):1615-9.
[2] Felkai P, Lengyel I, Szokoly M, Forgó G. Epidemiological data of Hungarian skiers' and snowboarders' medical problems. Orv Hetil. 2017 Apr;158(16):618-624.
[3] Felkai P, Clements CW 2nd. New methods for practice oriented post-graduate medical education: training of a ski-camp doctor in Hungary. Wilderness Environ Med. 2008 Summer;19(2):134-9.

Mental health benefits of a one-week, ski-based exercise intervention for primary brain tumor patients and their caregivers

*Nora Hansel * [1], Jule Rösener [2], Ralf Brandt [1], Johanna Engl [1,3,4], Lars Lemcke [1], Jens Clasing [5], Fabian M. Troschel [6], Rainer Wiewrodt [3], Walter Stummer [1], Eric Eils [2], Dorothee Wiewrodt [1]*

[1] Department of Neurosurgery, Münster University Hospital, 48149 Münster, Germany
[2] Department of Neuromotor Behavior and Exercise, Institute of Sport and Exercise Sciences, University of Münster, 48419 Münster, Germany
[3] Pulmonary Research Division, Department of Medicine A, Münster University Hospital, 48149 Münster, Germany
[4] Department of Neurosurgery, University Hospital, Saarland University, 66119 Saarbrücken, Germany
[5] Department of Surgery, Raphaelsklinik, 48143 Münster, Germany
[6] Department of Radiation Oncology, Münster University Hospital, 48149 Münster, Germany

Keywords: quality of life, primary brain tumor, caregivers, skiing intervention

INTRODUCTION: Patients with brain tumors often experience their commonly multimodal treatment as exceptionally exhausting. During treatment, moderate physical activity is recommended to stabilize physical and mental health for both patients and their caregivers [1]. In contrast, intense exercise such as skiing is typically discouraged due to concerns about potential harm. However, the feasibility of skiing in a multi-professional setting has been demonstrated recently [2]. This study examines the impact of a one-week skiing intervention on the quality of life (QoL) in brain tumor patients and their caregivers.

METHODS: The trial was designed as a non-randomized, prospective two-arm study (intervention group (IG) versus control group (CG)), both for patients and their relatives. Data were collected in March 2023 and March 2024. IG participated in a one-week skiing program in a self-catering lodge at an altitude of 1,400 meters in Austria with support from physicians, ski instructors, psycho-oncologists, and sports scientists. Participants engaged in at least four hours of downhill or cross-country skiing daily for six days. CG continued their regular daily exercise routines at home. QoL was measured using WHO5, EORTC, ASKU, distress thermometer, and HADS at four time points: one week prior, during, one week after, and 12 weeks post-intervention. Statistical analysis was performed using the Wilcoxon test.

RESULT/DISCUSSION: Of 34 participants, 30 completed the study. In the IG, 14 patients (mean age 47y ± 14y, 5 males) and 8 caregivers (mean age 42y ± 16y, 2 males) participated. The CG included 8 patients (mean age 56y ± 14y, 2 males), with no caregivers participating. After the ski excursion, IG patients reported clinically meaningful improvements in six categories (QoL, relationship satisfaction, psychological well-being, self-efficacy, anxiety, depression; $p<0.05$, all comparisons). Likewise, IG caregivers improved in four categories (health status, psychological well-being, self-efficacy, anxiety; $p<0.05$, all comparisons). The benefits persisted across all follow-up assessments. In contrast, CG patients reported no improvements at any time point.

CONCLUSION: In brain tumor patients and their caregivers, one week of skiing intervention facilitated by a multi-professional team led to several important mental health benefits, with effects sustained for at least three months.

REFERENCES:

[1] Forst et al. (2022). Factors associated with psychological distress in caregivers of patients with malignant gliomas. *Supportive Care in Cancer*, 30(7): 5811-5820.
[2] Troschel F.M. et al. (2020). Feasibility, Safety and Effects of a One-Week, Ski-Based Exercise Intervention in Brain Tumor Patients and Their Relatives: A Pilot Study. *Journal of Clinical Medicine*, 9(4): 1006.

LEVEL OF OVERESTIMATION AMONG DUTCH RECREATIONAL SKIERS: UNSKILLED TOURISTS IN THE MOUNTAINS

*Floriana Luppino[1] *, Merel van Diepen[2], Margien den Hollander-Gijsman[3], Kornelis Bartlema[4], Friedo Dekker[2]*

[1]Eurocross Assistance, Leiden, the Netherlands [2]Department of Clinical Epidemiology, Leiden University Medical Centre, the Netherlands [3]Department of Information Technology and Digital Innovation, Leiden University Medical Centre, the Netherlands [4]Department of Traumatology, Leiden University Medical Centre, the Netherlands

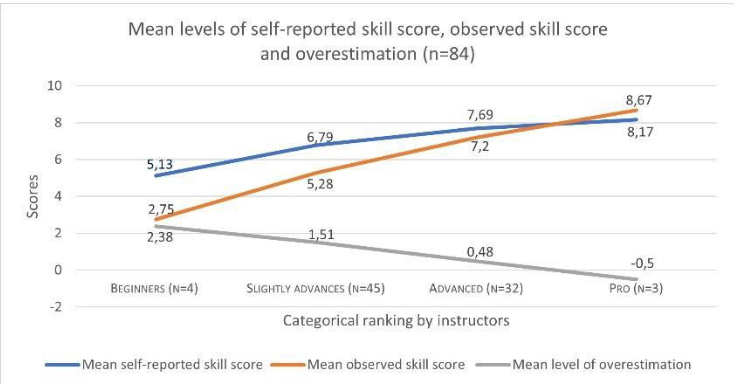
Keywords: recreational skiers, injury risk, overestimation.

INTRODUCTION: Recreational skiing is a popular winter holiday activity, but not without risk. Many factors have been attributed to the risk of injury, but the level of overestimation has never been examined. This study aimed to examine the level of overestimation (LO) and associated factors, and to identify the group of severe overestimators, among recreational skiers.

METHODS: 84 Dutch recreational skiers were asked to rate themselves (SRSS, self-reported skill score). While skiing downhill, they were objectively evaluated by two expert assessors (OSS, observed skill score). Potential associated factors and predictors for severe overestimation were assess by a questionnaire. The level of overestimation was categorized into 'no', 'mild' and 'severe'. Potential differences between these groups were analyzed, and regression analyses were performed to identify the factors associated with severe overestimation. To construct a profile of severe overestimators, the dataset was stratified based on three variables: gender, physical preparations and avoidance of certain weather conditions.

RESULTS/DISCUSSION: Overestimation was largely present (79.8%) and was severe in 32%. The LO decreased towards the more skilled skiers. Severe overestimators were mainly male, skied the least hours per day, were more avoidant, and showed the highest proportions of beginners and slightly advanced skiers. The profile of 'severe overestimator' is characterized by physically unprepared males, avoidant for certain weather circumstances.

CONCLUSION: Overestimation among recreational Dutch skiers is largely present, particularly among physically unprepared males, avoidant of certain snow and weather conditions. These features might function as a proxy to identify 'severe overestimators' in comparable populations. Preventive strategies should focus on increasing awareness, particularly among these subjects.



OPTIMISING SKI PERFORMANCE: A MULTI-SCALE ANALYSIS OF SKI–SNOW FRICTION IN COLD CONDITIONS

Kalle Kalliorinne [1,3], Roland Larsson [1], Andreas Almqvist [1,2]

[1]Machine Elements, Luleå University of Technology, Luleå, Sweden [2]Swedish Olympic Committee, Stockholm, Sweden, [3]Swerim, Luleå, Sweden

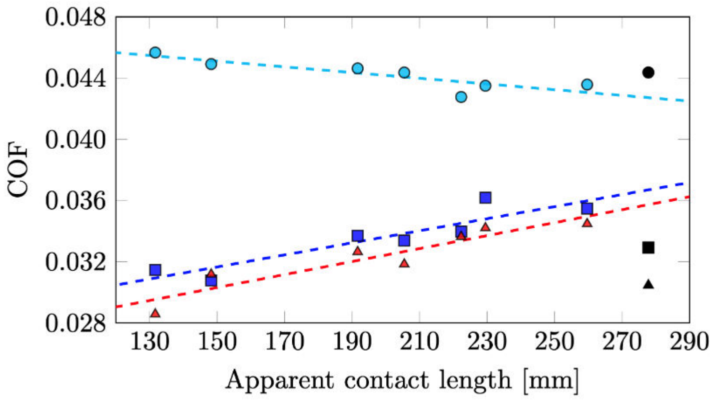
Keywords: Equipment, Gliding, Skiing, Sports technology

INTRODUCTION: Minimising ski–snow friction is essential for optimising performance in winter sports, especially under cold conditions, where resistive forces can significantly affect race outcomes. This study investigates how macro- and micro-scale parameters influence ski friction, offering new insights into ski design.

METHODS: We utilised an RTK-GNSS-equipped sled to quantify the coefficient of friction (COF) across eight ski pairs [1], each with varying contact mechanical properties. Testing was conducted under controlled snow conditions at three temperatures: −3°C, −8.5°C, and −13°C. Multi-scale characterisation of the skis was conducted using advanced numerical simulations [2], and we focussed primarily on the relationship between the COF and the apparent contact length. This is on par with the length ski technicians would typically use a 0.05 mm feeler gauge to find [3].

RESULTS/DISCUSSION: The results indicate that the apparent contact length is a significant factor in determining friction, particularly in colder temperatures.

After excluding the ski pair considered an outlier (marked in black), the COF vs apparent contact length relationships, for each temperature condition, were approximated using least-square fits. The dashed red, blue and cyan-coloured lines indicate that longer contact lengths are more effective at the coldest condition, −13°C, while shorter lengths reduce friction at the conditions with higher temperatures, −8.5°C and −3°C.



CONCLUSION: The present analysis highlights how temperature influences ski-snow friction, offering insights for optimising ski performance and provides practical guidelines for optimising ski performance in different environmental conditions. Future work should explore more conditions to validate the applicability of the findings.

REFERENCES:

[1] Kalliorinne, K., 2024, Luleå University of Technology Ph.D. thesis
[2] Kalliorinne, K., 2024, Lubricants
[3] Breitschädel, F. 2012, *Procedia Eng.*

A PORTABLE INSTRUMENT FOR ROLLING RESISTANCE CHARACTERIZATION OF ROLLER SKI WHEELS

Andréas Löfgren, Albert Hansson, Jonatan Larsen, Arvid Sandström, Dan Kuylenstierna

Chalmers University of Technology

Keywords: roller ski, rolling resistance, rolling friction, mechanical testing

INTRODUCTION: The rolling resistance of a roller ski wheel constitutes an important factor determining the outcome of roller ski competitions, yet there is a lack of equipment for effective characterization of the same. In the past this was less of a problem as most competitions were organized without restrictions on allowed wheel types. Each participant could freely select whichever wheel material they deemed most competitively advantageous, similar as is the case on snow. However, in recent years it has become increasingly common for roller ski competitions to restrict which wheel types are allowed, most commonly by restricting allowed wheels to so-called “standard-roll wheels” (also known as “grade-2 wheels”). Nevertheless, there exists no quantitative definition of standard-roll, and the variation among common available brands is large. The situation necessitates an instrument that can characterize the rolling resistance of roller skis with high precision and with efficiency in the testing procedure. A couple of attempts to develop such instruments have been done in the past, e.g., [1] presents an instrument based on a miniaturized treadmill and [2] presents an instrument based on a strain gauge. However, both these set-ups have drawbacks in terms of limited portability and/or that they require the wheels to be separated from the ski. The purpose of this work is to build a portable instrument for non-destructive characterization of roller ski resistance.

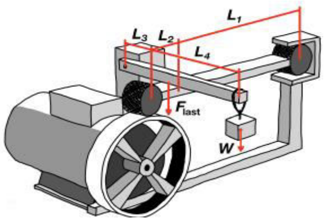


Fig. 1 Schematic of portable instrument for rolling resistance extraction.

METHODS: Fig. 1 illustrates the instrument designed in this work. It is based on an electrical motor driving a flywheel that drives a roller ski wheel. The power consumption of the electrical engine is a function of the frictional force between the roller ski wheel and the metallic flywheel. In its final implementation the motor is connected to a micro-computer programmed with a behavioral model for calculation of roller resistance as dependent on speed and load.

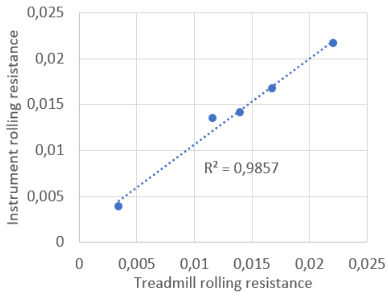


Fig. 1 Rolling resistance correlation between instrument and treadmill.

RESULTS/DISCUSSION: The developed instrument has been validated by means of five different roller ski wheels characterized by the instrument as well as on treadmill, measuring rolling resistance using a dynamometer. The correlation is presented in Fig. 2. In addition to the strong correlation demonstrated in Fig. 2, the reliability of the instrument is also validated by means of repeated measurements, revealing a precision better than 1.1% assessed from 10 repeated measurements.

CONCLUSION: A portable instrument for non-destructive rolling resistance characterization of roller skis has been developed. This tool can quantify the performance of different wheels and thus contribute to more fair roll-ski competitions in the future.

REFERENCES:

[1] M. Ainegren, P. Carlsson, and M. Tinnsten, Procedia Engineering, vol. 60, 2013
[2] C. Adolfsson et al., ”Rullmotståndsmätare… ”, Linköping University, Linköping, Sweden, 2017

INORGANIC SPUTTERED COATINGS TO WIN GOLD MEDALS AT WINTER OLYMPICS

*Pauline Lefebvre*1, Fabian Wolfsperger [2], Jean Herody[3], Matthias Jaggi [2], Arnaud Mantoux [1], Nicolas Coulmy [3], Pascal Hagenmuller [4], Elisabeth Blanquet [1]*

[1]SIMaP, Grenoble Alpes University, France [2]WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland
[3]French Ski Federation, France [4]Centre d'Etudes de la Neige, CNRM, Météo-France, Grenoble, France

Keywords: Coatings, Ski wax, Tribometer

INTRODUCTION: In cross-country skiing, reducing the friction coefficient between the skis and snow is essential for sportive performance [1]. Fluorinated waxes, i.e. containing perfluoroalkyl (PFA) are known for their hydrophobic properties and were remarkably efficient in wet snow conditions. However, the International Ski and Snowboard Federation (FIS) has banned fluorinated wax since winter 2023/2024 -for health and environmental reasons [2]. Since then, no alternative with equivalent performance has been found. This project aims to develop hard and hydrophobic coatings based on titanium nitride (TiN), aluminum nitride (AlN) and alumina (Al_2O_3) materials deposited on ski bases and UHMW polyethylene.

METHODS: The thin films were deposited using magnetron sputtering, a vacuum technique consist of creating a vapor from a target of the desired material that is then condensed onto the substrate, the ski bases. The vapor is created by a plasma from which ions bombard the target and eject atoms from it. The surface (contact angle, roughness, chemical composition), mechanical and thermal properties of the coatings were investigated. The friction coefficient of the coated samples was evaluated on snow with a linear tribometer (speed: 0.1 m/s, contact pressure: 50 kPa) in a cold-room at 0°C. Snow with different liquid water content were used for the tests.

RESULTS/DISCUSSION: The deposition on the ski base is possible at ambient temperature with adhesive and dense coatings. The coating thickness was evaluated by electronic microscopy between 50 and 200 nm depending on process parameters. Chemical analysis with XPS indicates the nitride films contain a relative high amount of carbon and oxygen. Only a few coatings, selected for their hydrophobicity and structural properties, were investigated in gliding tests. AlN and Al_2O_3-based coatings presented very high friction coefficient (0.2-0.3). TiN-based coating had the lower friction coefficient with a value of 0.11 on very wet snow, whereas a ski waxed with PFA friction coefficient was measured at 0.072. No correlation was found between the friction coefficient and neither the wettability nor the roughness. Other properties might have a major impact. Indeed, TiN is known for better mechanical properties [3] and lower thermal conductivity [4] which will be further investigated.

CONCLUSION: The deposition of sputtered coatings was realized with success and may be a promising technique for preparing competition skis. The versatility of this technique allows the use of several different materials from pure metals, to alloys and ceramics. For winter sport application, titanium nitride seems to be the most promising. Next, the project will focus next on TiN coatings with different properties and on multilayers based on TiN, known to improve mechanical and thermal properties [5].

REFERENCES:

[1] Moxnes, J. F. et al, 2013 J Sports Med
[2] Freberg, B. I. et al, 2010 Environ Sc & Techno
[3] Glocker, D. A., et al, 1995 Inst of Phys Publishing
[4] Moraes V. et al, 2016 J Appl Phys
[5] Samani, M. K., 2014 Thin Solid Films

ROLLING RESISTANCE COEFFICIENT OF VARIOUS ROLLER-SKI WHEEL TYPES AND MANUFACTURERS

Anna-Mia Brulin, David Sundström, Mats Ainegren*
Sports Tech Research Centre, Department of Engineering, Mathematics and Science Education, Mid Sweden University, Östersund, Sweden

Keywords: cross-country skiing, biathlon, roller skiing, ski friction

INTRODUCTION: Roller skis are used in training and competition to imitate cross-country skiing during the snow-free season, where different wheels are used for classic and skate roller skiing. Roller-ski wheels are typically categorised based on rolling resistance, with race and standard wheels commonly used in competition. The experience among athletes and coaches is that the rolling resistance coefficient (μR) of the roller-ski wheels varies not only between manufacturers but also within the same series of wheels. However, this has been sparsely investigated in previous studies [1][2]. The difference in μR can significantly influence the race performance [2]. Therefore, the aim of the study was to determine the μR of various types of roller-ski wheels from different manufacturers.

METHODS: Measurements of the rolling resistance of unused and pre-heated [1] roller-ski wheels were carried out with newly developed equipment, consisting of an electrically powered spinning Ø60-cm aluminium cylinder. To record the forces acting on the roller-ski wheel, the wheel was mounted to a fork attached to a 3-D load cell (NET Force/Torque sensor Mini58, ATI Industrial Automation, Apex, USA). μR was estimated as the ratio between the tangential and the normal forces measured by the load cell. The measurements were performed at a cylinder-periphery speed of 20 km/h with a normal force of 300 N. A sample size of eight wheels of each type was measured, including both race and standard wheels for skate and classic styles. The wheels were all non-ratcheted and sourced from manufacturers Marwe, Swenor, SWIX and FF-ski. One-way ANOVA and Bonferroni post hoc tests were used to determine any significant differences ($P<0.05$) in μR between the different manufacturers.

RESULTS/DISCUSSION: Significant differences in μR were found between all manufacturers for the tested skate wheels ($P<0.001$) and classic wheels ($P<0.001$), except for Marwe race vs Swenor race classic wheels ($P = 0.058$, ns), see Fig 1. The range of variation in μR between means for standard wheels was 0.011, 52% of mean (Skate) and 0.008, 41% (Classic), and for race wheels 0.005, 46% (Skate) and 0.001, 13% (Classic). Further measurements need to be made to study whether μR for different types of wheels is influenced by different normal forces and speeds.

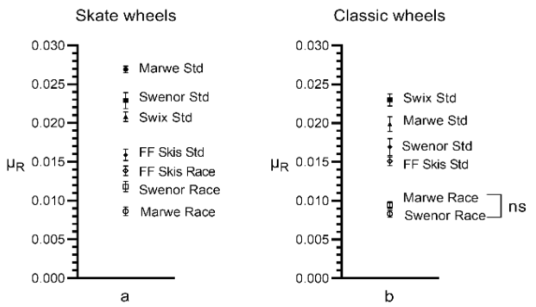


Figure 1. Rolling-resistance coefficients (mean ± SD) for different manufacturers of skate (a) and classic (b) roller-ski wheels of standard (filled symbols) and race (open) types. Note: ns = nonsignificant.

CONCLUSION: The results show that there are large differences in μR between different manufacturers of equivalent types of wheels, which can be decisive for the roller skier's performance.

REFERENCES:
[1] Ainegren M, et al, 'Rolling resistance for treadmill roller skiing' 2008 Sports Eng.
[2] Schindelwig K, et al, 'Determination of the rolling resistance of roller skis' 2017 J. Sports Eng. Technol.

DEVELOPMENT AND VALIDATION OF A NEW STANDARD FOR ROLLER-SKI WHEEL CLASSIFICATION

Albert Hansson[1], Andréas Löfgren[1], Tobias Westman, Jonas Braam[2], Dan Kuylenstierna[1]

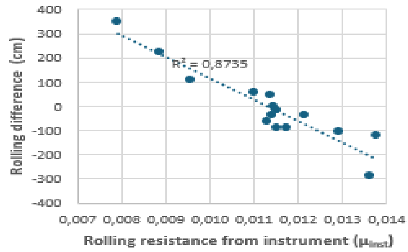
Chalmers University of Technology[1], Svenska Skidförbundet[2]

Keywords: roller ski, rolling resistance, rolling friction, validation

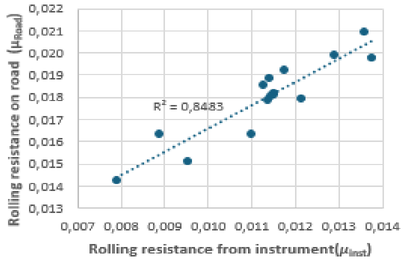
INTRODUCTION: The rolling resistance of a roller ski wheel constitutes an important factor determining the outcome of roller ski competitions. In the past this was less of a problem as most competitions were organized without restrictions on allowed wheel types and it was up to each skier to select material at best effort, similar as is the case on snow. However, in recent years it has become increasingly common for roller ski competitions to restrict which wheel types are allowed, most commonly by restricting allowed wheels to so-called “standard-roll wheels” (also known as “grade-2 wheels”). This is a problem as long as there is no quantitative definition of standard-roll. This work evaluates a novel instrument for rolling resistance characterization [1] and evaluates its outcome versus field tests.

METHODS: 12 pairs of commercial roller skis categorized as grade 2 were collected and tested with three different methods: 1. Pair-roll tests down a hill, 2. Pole-force measurements [2] in flat-terrain double poling, 3. Instrumental rolling resistance characterization based on an electrical motor driving a metallic flywheel that rotates the wheel under test. Data from the three tests were compared with the purpose to establish correlation and define a standardized classification based on results from the instrument.

RESULTS/DISCUSSION: Fig. 1(a) presents correlation between the rolling resistance measured by the instrument and outcome of the pair-roll comparison between the ski pair under test and a defined pair of test skis. Fig. 1(b) presents the correlation between rolling resistance from the instrument and rolling resistance extracted from pole-force data. In both comparisons, the correlation is strong with R^2=0.88 and R^2=0.85, respectively. The strong correlation indicates that wheels can be categorized by the standardized instrumental test.



(a)



(b)

Fig. 1 Correlation between instrument and (a) pair-roll comparison and (b) rolling resistance extraction from pole-force measurements.

CONCLUSION: A new standard for instrumental rolling-resistance characterization has been established. The method is validated versus field roll-tests and guide-lines for grade 2 wheels are defined. It is recommended that a grade 2 wheel presents a rolling resistance in the range 0.011-0.012 measured against a smooth metallic flywheel with diameter 20 cm rotating with an angular velocity corresponding to 20 km/h for the wheel under test. The rolling resistance value is registered after the wheel has reached saturated temperature. To allow margins for process tolerance, wheels in the range 0.010-0.013 are allowed to be categorized as grade 2.

REFERENCES:

[1] A. Lövgren et. al, Submitted to *10th International Congress on Science and Skiing (ICSS)*, Val di Fiemme, Italy, January 28-31, 2025.

[2] D. Kuylenstierna et., *8th International Congress on Science and Skiing (ICSS)*, Vuokatti, Finland, March 11-15, 2019.

EFFECT OF CRYSTALLINITY ON WEAR PROPERTIES OF UHMWPE WITH VARYING MOLECULAR WEIGHTS

Marko Bek[1,2], Roland Kádár[2], Nazanin Emami[1]*

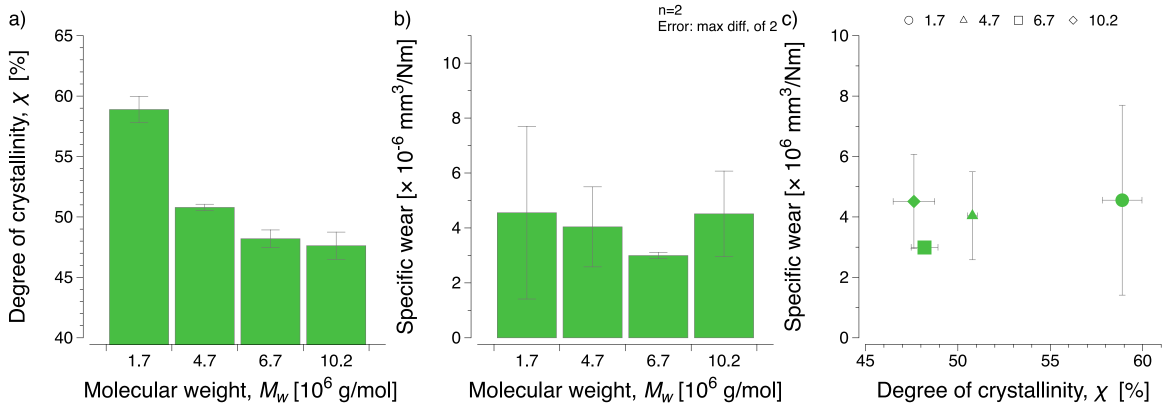
[1] Department of Engineering Sciences and Mathematics, Luleå University of Technology, Luleå, Sweden, [2] Department of Industrial and Material Science, Chalmers University of Technology, Gothenburg, Sweden

Keywords: UHMWPE, Crystallinity, Wear

INTRODUCTION: Ultra High Molecular Weight Polyethylene (UHMWPE) is a semicrystalline polymer valued for its exceptional wear properties. It a popular choice for applications such as sliding contacts, gears, and medical implants. Enhancing the durability and reducing the wear of UHMWPE are key areas of ongoing research, with strategies including crosslinking [1], nano- and microparticle reinforcement [2], and varying molecular weights [3]. This study investigates the effect of molecular weight (Mw) on crystallinity and its subsequent impact on the wear properties of UHMWPE, focusing on four grades with widely varying Mw.

METHODS: This study evaluates how molecular weight (Mw) influences crystallinity and wear performance in UHMWPE. Four grades with varying Mw (1.7 to 10.2 M g/mol) were analysed using differential scanning calorimetry (DSC) to determine crystallinity and a Pin-on-Disc tribometer to measure wear under controlled conditions simulating sliding contact.

RESULTS and DISCUSSION: Higher Mw generally reduced specific wear, even though crystallinity decreased with increasing Mw. Interestingly, the highest Mw grade deviated from the general trend, indicating that other structural or mechanical factors may also contribute to wear behaviour at extreme molecular weights.



CONCLUSION: The findings demonstrate that balancing the effects of molecular weight and crystallinity should be considered when selecting a ski base material. While higher molecular weight generally reduces wear, the interplay between molecular structure and material properties is complex. This means that choosing a material with the right molecular design can lead to enhanced performance, such as longer durability during use.

REFERENCES:

[1] Wang, Zirui, et al. "High crystallinity makes excellent wear resistance in crosslinked UHMWPE." *Polymer* 280 (2023).

[2] Kneissl, Lucas M., et al. "Mechanical properties and tribological performance of polyoxymethylene/short cellulose fiber composites." *Polymer testing* 128 (2023).

[3] Vadivel, Hari Shankar, et al. "Do the particle size, molecular weight, and processing of UHMWPE affect its thermomechanical and tribological performance?." *journal of materials research and technology* 12 (2021).

ON THE HYDRODYNAMIC LUBRICATION OF SKIING

Roland Larsson[1*], *Joakim Sandberg*[1], *Gustav Hindér*[1], *Andreas Almqvist*[1]

[1] Division of Machine Elements (Ski & Snow Lab), Luleå University of Technology, Sweden

Keywords: ski friction, grind structure, lubrication, melt water theory

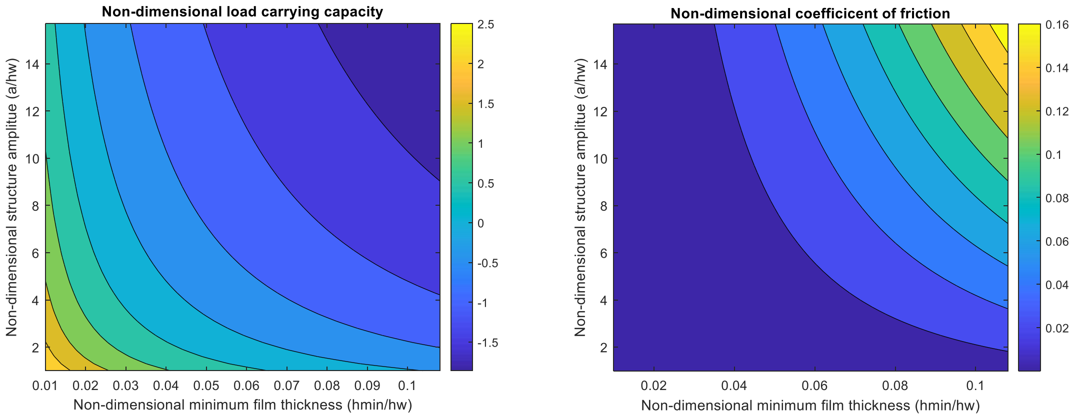
INTRODUCTION: Can friction form a thick, low-friction film in the contact between ski and snow? Is the melting rate sufficiently large for that? These are questions to be discussed in this paper. Lubrication theory can be applied to the ski friction problem, since proper lubrication of the ski requires that the melting rate must balance the amount of water pushed out from the contact between a ski base asperity and the snow. If we assume that the base of the skis is ground with longitudinal ridges and valleys and is placed in contact with a smooth snow surface, then the flow balance equation reads:

$$\frac{\partial}{\partial y}\left(h^3 \frac{\partial p}{\partial y}\right) = -12\eta \frac{\partial h_m}{\partial t} = -12\frac{\eta^2 u^2}{hL\rho}, \qquad (1)$$

where p is water-film pressure, h is the thickness of the water film, u is the speed, and ρ, η, and L, are water density, viscosity, and latent heat, respectively. The RHS of (1) can be interpreted as a "melt squeeze effect" since $\partial h_m/\partial t$ is the melting rate.

METHOD: The flow balance equation (1) can be solved analytically for flat grinds and numerically for more complex grind textures. In both cases it is possible to determine the load-carrying capacity (LCC) of a single ridge, and the coefficient of friction (COF).

RESULTS/DISCUSSION: The results show that there is an obvious difference between grind textures with different amplitude. The figure below shows non-dimensional heat maps of LCC and COF vs grind amplitude and water film thickness. It is also possible to determine the melting rate to be in the order of magnitude of 1 mm/s at high speeds. This implies that the snow surface will change during one passage of one skier. The implications of this will be discussed during the presentation.



Load carrying capacity of one ridge (left) and coefficient of friction (left)

CONCLUSION: The friction melt lubrication theory may be valid if there is sufficient time of contact between the ski and snow. However, it is far from clear that there is time enough for the friction to generate a melt film that creates a hydrodynamically lubricated situation under situations with dry and/or cold snow surfaces.

MECHANICAL EFFICIENCY - PIN VS FREERIDE BINDINGS

Tobin Arden, Isaac JL Burgess, Sami Samuels, John Seifert, James Becker*

Department of Food Systems, Nutrition, and Kinesiology, Montana State University, Bozeman, USA

Keywords: Ski Mountaineering, Mechanical Efficiency, Bindings

INTRODUCTION: Previous studies on competitive ski mountaineering (skimo) athletes have examined the relationship between ankle weighting and metabolic cost [1]. However, no studies have examined the relationship of binding weight and energy cost in recreational skimo skiers who ski at much slower speeds than racers. This is impactful for skiers when choosing bindings, as they generally have two choices, pin (P; ~400g) or freeride (FR; ~900g) bindings. Therefore, the purpose of this study was to compare mechanical efficiency (ME), metabolic work (MW), and vertical work (VW) responses to P and FR bindings while skinning on a treadmill.

METHODS: Fifteen healthy participants (M:7, F:8, age: 21±1.5yrs, height: 1.81±0.06m, mass: 78.1±7.3kg), with at least two years of skimo experience, were recruited for this study. An incremental maximal VO2 protocol was used to establish the relationship between HR, VO2, and RER. Following a 5-minute warm-up, participants skinned at 1.11 m/s for 3-minute trials on a treadmill at 8% and 15% grades using P or FR bindings. For the 15% grade, a second trial at 0.62 m/s was completed, determined by calculating the matched work to the 8% condition. HR was used for the estimated metabolic rate calculation. The ratio of VW to MW was used to calculate ME [2]. A 2x2 ANOVA was used to compare responses between binding and grade.

RESULTS/DISCUSSION: A main effect of grade was observed for VW at 1.11 m/s ($p<.001$) and 0.62 m/s ($p<.001$). A main effect of grade ($p<.001$) was also noted for MW at 1.11 m/s, with greater MW at 15% grade than 8% grade, while there was a trend for main effect of binding ($p=.072$). A main effect of grade for 1.11 m/s ($p<0.001$) and 0.64 m/s ($p<0.001$) was observed for ME, with greater efficiency at 15% grade. However, no main effect of binding was observed for ME at 1.11 m/s ($p=.37$) or 0.64 m/s ($p=.75$). These results indicate that no statistical differences between the bindings were present while skiing on a treadmill. Unlike snow, skiers are unable to glide on the ski treadmill, which may contribute to the main effect of grade on ME.

Table 1: Mean and standard deviations for matched speeds and intensities at 8% and 15%

	8%, 1.11 m/s		15%, 1.11 m/s		15%, 0.62 m/s	
	Pin	Freeride	Pin	Freeride	Pin	Freeride
Vertical Work (J)	68.0±8.2	68.9±8.3	126.6±15.3	128.3±15.4	70.9±8.6	71.8±8.6
Metabolic Work (W)	822.1±240.4	858.7±246.3	1041.7±322.9	1073.7±336.7	702.4±279.3	703.6±244.6
Mechanical Efficiency (%	8.7±1.6	8.5±1.8	12.9±2.6	12.7±2.7	11.1±3.0	11.15±3.3

CONCLUSION: Given the testing protocol, binding type and weight has minimal influence on work and efficiency. In contrast, grade and skiing speed have significant influence on work and efficiency during recreational skimo. Further analysis should be performed on snow to generalize these results to binding choice for on-snow skiing.

REFERENCES:

[1] Tosi, P., et al, 2009 Sports Med. Phys. Fitness.
[2] Praz, C., et al, 2016 European Journal of Applied Physiology

DOES BINDING WEIGHT INFLUENCE PHYSIOLOGICAL RESPONSE? A LABORATORY BASED STUDY

*Sami Samuels** [1], *Isaac Burgess* [1], *James Becker* [1], Michael Lasshofer [2], *John Seifert* [1]

[1] Department of Food Systems, Nutrition, and Kinesiology, Montana State University, Bozeman, USA; [2] Department of Sport Science and Kinesiology, University of Salzburg, Salzburg, Austria.

Keywords: Ski Mountaineering; Ski Bindings; EMG

INTRODUCTION: In ski mountaineering (skimo), the ski binding serves as an essential connection point between the skier and the ski, allowing the heel to move freely on the ascent and locking into place to ski downhill. Traditionally, the lighter options of pin (P) bindings have been used, however within recent years the development of the heavier freeride (FR) bindings have gained popularity due to additive safety features such as adjustable DIN settings. Having different binding options allows recreational ski mountaineer's the opportunities to select a binding to best fit their needs. However, previous skimo studies have shown that increasing equipment weight increases metabolic cost of competitive skiers [1]. It is not known how additional weight affects recreational skiers. The purpose of this study is to compare the metabolic cost and muscle activity between P and FR bindings during uphill treadmill skiing in recreational skimo skiers.

METHODS: Thirteen recreational ski mountaineers with at least two years of skimo experience were recruited for this study (M:7, F:6, Age: 21±1.5 yrs, height:1.81±0.06 m, mass: 78.1±7.3 kg). Participants were tested on 8% and 15% grades at a speed of 1.1 m/s (3.96 kph). Each participant used Atomic Backland 85 UL skis with Atomic Backland Tour (398g) and Shift (915g) bindings. Participants skied for 3 minutes with each binding at each gradient and speed. Heart rate and EMG data was collected for the last 30 sec of each trial. VO_2 data was calculated from the HR-VO_2 relationship established from a walking VO_2max test. EMG data was recorded from rectus femoris, biceps femoris, vastus medialis, and medial gastrocnemius. RMS was calculated from 15 stride cycles, and time normalized. A 2x2 ANOVA was used to statistically analyze data.

RESULTS/DISCUSSION: No differences between bindings were found for HR and VO_2. There was a significant main effect of grade for HR ($p=0.007$) and VO_2 ($p=0.008$). No differences between bindings or grades were observed for RMS of any of the muscles.

Table 1. Heart rate, VO_2, and EMG Data by Binding and Grade (Mean ± Standard Deviation).

	8% P	8% FR	15% P	15% FR
Heart Rate (bpm)	149±20	153±19	167±15	166±16
VO_2 (ml/kg/min)	31.7±8.4	34.1±8.8	38.7±8.9	38.9±8.1
Biceps Femoris (mV)	0.0018±0.0016	0.0017±0.0009	0.0021±0.0012	0.0021±0.0009
Medial gastrocnemius	0.0026±0.0019	0.0025±0.0016	0.0026±0.0015	0.0023±0.0012
Rectus Femoris (mV)	0.0015±0.0004	0.0015±0.0005	0.0016±0.0005	0.0016±0.0004
Vastus Medialis (mV)	0.0026±0.0012	0.0025±0.0011	0.0030±0.0013	0.0032±0.0017

CONCLUSION: Binding type/weight has minimal influence on metabolic cost and muscle activity during treadmill skiing up to a 15% grade. Future studies should be performed to define on-snow physiological and biomechanical influences of given bindings.

REFERENCES:

[1] Tosi, P. et al., J. Sports Med. Phys. Fitness (2009)

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KINEMATIC DIFFERENCES IN SKI MOUNTAINEERING BINDINGS DURING TREADMILL SKINNING

*Isaac Burgess *, Samantha Samuels, John Seifert, James Becker*
Department of Food Systems, Nutrition, and Kinesiology, Montana State University, Bozeman, USA

Keywords: Backcountry Skiing, Ski Mountaineering, Bindings, Biomechanics

INTRODUCTION: Previous studies on competitive ski mountaineering (skimo) athletes have shown that increasing equipment weight increases metabolic cost [1]. However, whether weight differences influence skinning kinematics remains unknown. This is particularly important for recreational skimo participants when purchasing equipment, as they generally choose between lightweight pin (P) or heavier freeride (FR) bindings. Therefore, the purpose of this study was to compare lower body kinematics and spatiotemporal measures while skinning on different treadmill grades in both P and FR bindings.

METHODS: Thirteen participants with at least two years of skimo experience participated in this study. In a randomized order, participants skinned on matching skis mounted with either P or FR bindings for 3-minute stages at 1.1 m/s and grades of 8 and 15%. Whole body kinematics were recorded using a 6-camera motion capture system from which cycle time, length, and frequency, as well as torso, hip, knee, and ankle kinematics were calculated. Differences across bindings and grade were evaluated using 2x2 repeated measures ANOVA.

RESULTS/DISCUSSION: There were main effects of binding for cycle time ($p = .005$), step length ($p = .005$), and step rate ($p = .004$) with longer and slower strides in the FR binding. Swing time showed main effects of both binding ($p = .017$) and grade ($p < .001$), with swing time being longer in the FR binding at 8%. All joint kinematics were not significantly different between bindings with all showing main effects of grade.

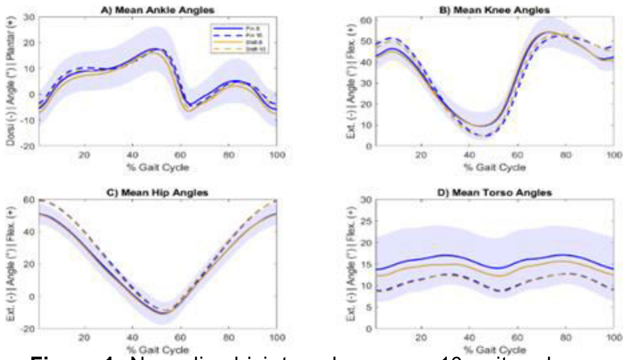


Figure 1. Normalized joint angles across 10 gait cycles. Note the offset in curves due to grade.

Table 1. Cycle metrics mean and standard deviations, averaged across 10 gait cycles

	Pin 8%	Pin 15%	Freeride 8%	Freeride 15%
Cycle Time (S)	1.24± 0.06	1.22 ± 0.06	1.27 ± 0.07	1.25 ± 0.06
Step Length (m)	1.39 ± 0.07	1.37 ± 0.06	1.42 ± 0.08	1.40 ± 0.08
Step Rate (Step/Min)	76.0 ± 2.40	74.8 ± 2.86	77.8 ± 1.74	76.9 ± 2.23
Swing Time (S)	0.49 ± 0.01	0.47 ± 0.01	0.51 ± 0.01	0.49 ± 0.01

With the heavier FR binding the ski remains closer to the ground and glides further resulting in the longer step length, and when at a controlled speed, a slower step rate. These findings are consistent with previous studies examining cycle characteristics with increasing grade [2] and provide insight regarding the effects of increased binding weight on kinematics and cycle characteristics while skinning.

CONCLUSIONS: In a laboratory setting, binding type influences cycle characteristics but not kinematics while skinning. Further analyses on snow are required to generalize these results to actual skimo environments.

REFERENCES

[1] Tosi, P. et al., J. Sports Med. Phys. Fitness (2009);
[2] Lasshofer, M. et al. Frontiers in Sports and Active Living (2022).

COMPARISON OF THE FLEX INDEX OF SKI TOURING BOOTS OBTAINED USING THREE DIFFERENT TESTING METHODS

Giuseppe Zullo[*1], *Leonardo Prenol*[1], *Lorenzo Crosetta*[2], *Martino Colonna*[2], *Nicola Petrone*[1]

[1] Department of Industrial Engineering, University of Padova, Padova, Italy; [2] Department of Civil, Chemistry, Environmental, and Material Engineering, University of Bologna, Bologna, Italy

Keywords: ski boot, flex index, bench test, ski touring equipment

INTRODUCTION: Ski boots are a fundamental piece of ski gear which skiers may choose privileging cost, comfort, or performance. The key number which drives the choice is the flex index, somehow representative of the whole performance of the boot. The flex is a measure of how much the boot resists to sagittal flexion when a moment on the ankle is applied. Despite providing a clear and standardized definition may seem quite trivial on a technical point of view, the flex definition is highly variable between brands and boots [1-2]. This work compares the flex of three ski touring boots obtained with three different methods: flex machine, walking simulator, in vivo.

METHODS: Three ski touring boots sized 26.5 MP were tested at room temperature (20° C ±5°) to determine their flex. Buckle closure was set to three levels. The first test was conducted on a 1DOF machine with a linear actuator and an articulated metal prosthesis. A second test used a 3DOF walking simulator with an articulated silicone prosthesis. An in-vivo test was finally setup using a BTS P-6000 force plate and a SMART motion capture system to capture angle and moment about the subject ankle. In all the three test the boot was fixed to a truncated ski with touring bindings and the shank angle was cyclically varied with an amplitude of 10° from the neutral position. Flex index was calculated as the ankle moment at +10° of flexion from the neutral position [1].

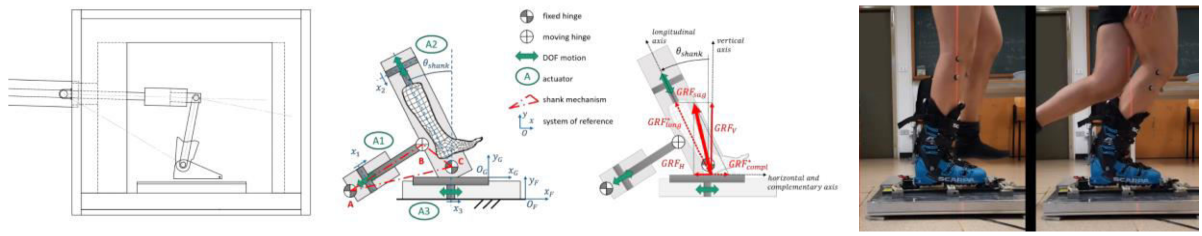
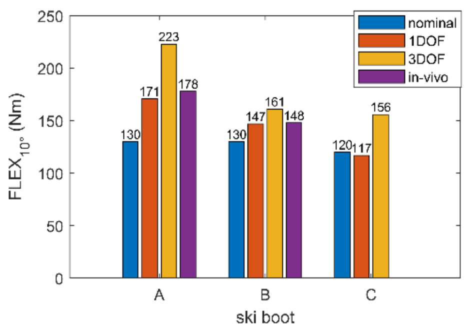


Figure 1. Test methods: 1 DOF machine; 3 DOF machine; in-vivo.

RESULTS/DISCUSSION: Flex index was different to the nominal value and was dependent on the method used. Differences could be attributed to prosthesis size and stiffness, but also to machine kinematics. These observations confirm the need to standardize the machine and prosthesis used to calculate the flex, as well as consolidating its definition. In vivo tests are quite close to pure bench test but could potentially introduce further variability and are difficult to standardize.



CONCLUSION: Flex index measure confirms to be subject to variability and should be revised and standardized. Future directions aim to use instrumented skis and boots to measure boot loads and kinematics in skiing, possibly redefining flex index definition. Multiple DOF walking simulators could then be used with these data to produce controlled and standard measures.

REFERENCES:
[1] Petrone, N. et al, 2013 Sport Eng.
[2] M. Knye, M. et al, 2016, Procedia Engineering.

EFFECT OF SKI TOURING BINDING DESIGN ON LOAD DISTRIBUTION BETWEEN TOE AND HEEL PIECES

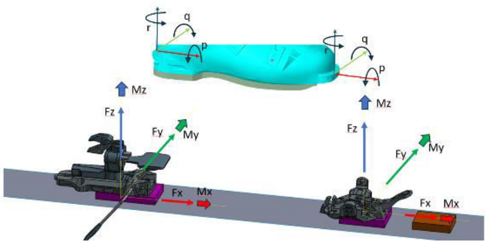
*Lorenzo Crosetta*1, Giuseppe Zullo 2, Martino Colonna [1], Nicola Petrone [2]*

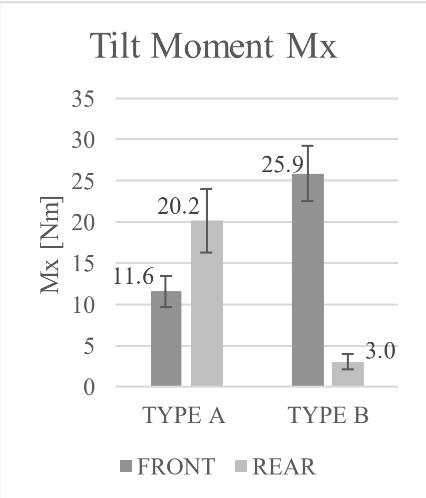
[1] Department of Civil, Chemistry, Environmental, and Material Engineering, University of Bologna, Bologna, Italy;[2] Department of Industrial Engineering, University of Padova, Padova, Italy

Keywords: Ski Touring; Ski Binding; Load Distribution, field test.

INTRODUCTION: In modern skiing, bindings serve as the sole interface between boots and skis. Therefore, all forces transmitted between boot and ski must first pass through the bindings, ultimately influencing skiing performance. In the context of ski touring, based on the type of attachment/interface to the boot sole, three categories of bindings can be identified: Alpine (A), Pin (B), and Hybrid (C). The first type features a clamping mechanism for both the heel and toe. The second utilizes two metal pins at the rear and a hinge at the front. The last combines the alpine system at the heel with the pin hinge at the front. Previous research has already demonstrated that these three types of bindings exhibit different safety performance characteristics [1]. The present study aims to examine how loads are distributed between the toe and heel pieces during a skiing session.

METHODS: Field tests were conducted using the method proposed by Zullo et al. [2] to measure the loads between skis and bindings (fig.1). A preliminary test was conducted with a pro skier (mass: 75kg; boot size: 27 MP) skiing freely on blue slope using a pair of Kastle skis equipped with the load cells (on the right side) and cat A, B bindings.





RESULTS/DISCUSSION: Results show that for the Alpine binding, the distribution is quite balanced, with the rear piece primarily absorbing the torque. In contrast, for the Pin binding, we observed a significant contribution from the front binding, reaching up to 90%. This difference could be due to higher compliance of the rear piece in Pin bindings. From a user perspective, the different distribution of Mx should be representative of a different feeling during turning. From a boot manufacturer perspective, this could be helpful in designing ski boots with optimal performance and weight.

CONCLUSION: Understanding this load distribution is important both for identifying potential malfunctions in release systems and as a tool for the design and development of ski boots. The preliminary test described set a starting point for a wider test campaign including more subjects and cat C bindings to take place in the upcoming ski season. Furthermore, this study can contribute to the identification of standardized methods for testing ski boot performance using lab bench simulators.

REFERENCES:

[1] Senner , V. et al, 2021 Journal of Science and Medicine in Sport
[2] Zullo, G et al, 2023 Sensor

THE EFFECT OF DIFFERENT WIDTHS ON SKI TOURING ENGINEERING PARAMETERS AND SUBJECTIVE EVALUATIONS

Matteo Rinaldi (*) [1], Giuseppe Zullo [1], Sebastiano Medardo [2], Nicola Petrone [1]

[1] Department of Industrial Engineering, University of Padua, Padova, Italy; [2] Tecnica Group, Giavera del Montello, Italy

Keywords: ski touring, lab test, in-field test, skiing performance, skiing safety

INTRODUCTION: Despite touring skis need to be primarily lightweight to facilitate the ascent, modern trends require them to also perform on groomed slopes, meaning they should be easy to initiate, control, and exit turns. Proper equipment evaluation, based on field and lab tests, is crucial to optimize ski performances and reduce injury risk. This study aims to evaluate the differences in bench loads, in-field loads, and subjective evaluation of touring skis with increasing widths to determine how ski width affects bench and perceived performance.

METHODS: Three pairs of Blizzard ZeroG touring skis were analyzed in three available widths: 85, 95 and 105 mm. Edge Load Profile curves of the skis were obtained at edging angles ranging from 0° to 60° using a ski test bench [1]. The skis in-field performances were then evaluated by six ski instructors by means of a questionnaire. Meanwhile, skiing Ground Reaction Forces were collected using compact load cells mounted under the ski bindings [2] during pole slaloms. Collected bench test data and field data were analyzed to assess ski turning performance and compared with perceived differences by skiers.

RESULTS/DISCUSSION: Bench test results showed that the ZG95 had the highest and outermost loads at both the tip and tail sections, compared to other skis. This suggests that ZG95 showed the highest effective length both during turn entry and exit. Field measurements with the load cell system showed increased roll torque Mx with increased width, as expected. Ski instructors' subjective evaluations selected the ZG95 as the overall best ski, followed by ZG85. Interestingly bench tests results matched with subjective results. Highest roll torque Mx experienced for ZG105 in external turns represents an increased varus moment at the knee, that can be also associated with an higher injury risk.

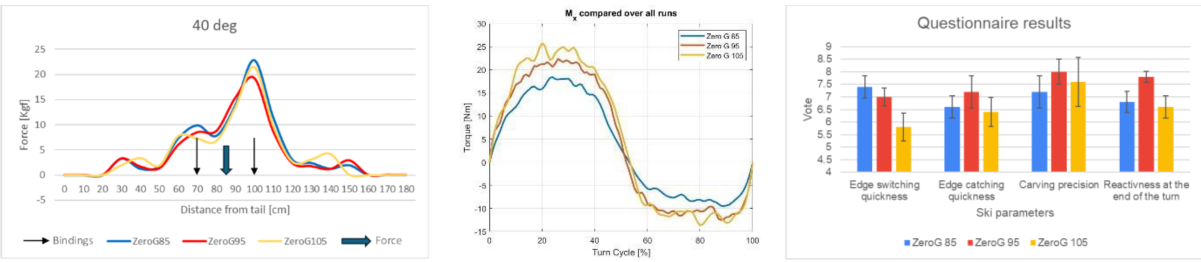


Figure 1: Edge load profile curves, roll torque and subjective evaluation of the three skis.

CONCLUSIONS: Bench and field tests effectively captured differences in performance among the ZeroG skis with different width. These differences were perceived also by skiers. Blizzard ZeroG 95 showed best performance in initiate, control, and exit turns, followed by ZeroG 85, suggesting that a narrower ski can be easier to switch and can respond more quickly to the skier's input. All ski tests were performed on groomed snow: but wider skis are more suitable for softer snow. Therefore, similar tests should be repeated in soft snow (and with corresponding foam surrogates in bench tests) to assess how ski performance and perception vary in this different condition.

REFERENCES:
[1] Petrone N., 2012 Procedia Engineering
[2] Zullo G. et al, 2023 Sensors

RISK MANAGEMENT IN ALPINE SKI RACING: EVERY PIECE OF THE PUZZLE COUNTS!

Jörg Spörri [1,2]

[1] Sports Medical Research Group, Department of Orthopaedics, Balgrist University Hospital, University of Zurich, Zurich, Switzerland; [2] University Centre for Prevention and Sports Medicine, Department of Orthopaedics, Balgrist University Hospital, University of Zurich, Zurich, Switzerland.

Keywords: athlete, injury, illness, prevention, return to sport

Compared with those in other Olympic winter sports, the health risks associated with alpine ski racing are relatively high.[1] Risk management strategies are central to protecting the health of athletes,[2] but systematic, holistic and/or long-term orientated approaches are widely lacking. This is particularly because risk causality in alpine ski racing is multifactorial and complex,[3] and prevention and return-to-sport measures must consider a wide range of relevant stakeholders, intervention areas and target groups.[2] It is also often necessary to balance different health, performance and business interests, making effective health protection for athletes even more challenging. Effective risk management is therefore much more than just performing a specific neuromuscular prevention exercise or developing protective sports equipment, and every piece of the puzzle counts!

The aim of this keynote presentation is to provide the audience with a comprehensive overview of the current knowledge on the subject and to derive evidence-based risk management strategies for alpine ski racing. In the first part of the presentation, the available research on risk management in alpine ski racing will be systematically summarised and explored in all its aspects and in relation to contextual factors such as sport, sex and competition level. The second part of the presentation will focus on athlete-related risk management strategies and their build-up as part of the athlete's long-term development pathway. Finally, in the third and concluding part of the presentation, a selection of specific implementation issues related to injury reporting, warm-up, training/testing and return to sport in alpine ski racing will be critically discussed, and potential solutions will be illustrated with best practice examples.

REFERENCES:

[1] Soligard, T. et al, 2023 Br J Sports Med
[2] Bonell Monsonís, O. et al, 2024 Inj Prev
[3] Kiers, K. et al, 2021 BMJ Open Sport Exerc Med

THE EFFECT OF INCREASED GATE OFFSET IN FLAT TERRAIN ON SKIER MECHANICS FOR MALE AND FEMALE WORLD CUP ALPINE SKIERS

*Ivar Hereide Mannsåker *[1], Robert Cortas Reid [1,2], Petter Husevåg Jølstad[1,2], Matthias Gilgien [1,2,3]*

[1] Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway [2] Sport Science, Norwegian Alpine Ski Team, Oslo, Norway [3] Center of Alpine Sports Biomechanics, Engadin Health and Innovation Foundation, Samedan, Switzerland

Keywords: biomechanics, injury prevention, course design, medicine

INTRODUCTION: In World Cup competitive alpine skiing, the risk of injury is relatively high compared to other Olympic winter sports [1]. While injuries in giant slalom (GS) were found to be primarily linked to the mechanics of turning (i.e. high turn speeds, small turn radii, large ground reaction forces and high impulse), injuries in downhill and super-G were more associated with speed and impacts [2]. Expert stakeholders see course-setting as the primary measure to reduce injury risk [3]. Biomechanical research has shown that course-setting manipulations are suitable to reduce injury risk factors such as speed, forces, turn radii, inward lean, etc. [4,5]. However, these effects were only found in experimental settings in steep terrain and for a few turns [4] or in a competition setting with one forerunner only. Therefore, this study assesses the effect of a series of gates with increased offset on skier mechanics in flat terrain.

METHODS: 5 male and 2 female World Cup skiers, members of the Norwegian alpine ski team, participated in the study. An open rhythmic course was set on a slope with an average incline of 13 degrees with an average gate distance of 27.0m and a 6.6m offset. Athletes skied first in that original course (course 1) before the gate offset was increased by 1.0m (course 2) and later by 1.5m (course 3). Athletes skied three runs in each of the courses. Terrain and course set were measured using static differential GNSS. Athletes carried a differential GNSS from which speed, ground reaction force, turn radius and impulse (the integration of ground reaction force over time) were calculated. Athletes also subjectively assessed the consequences of the course set changes.

RESULTS/DISCUSSION: In courses 2 and 3, where offset was increased by 1.0m, resp 1.5m compared to the original course (course 1) speed was reduced. Each additional gate with increased offset lead to an additional reduction in speed. Course 2, where offset was increased by 1.0m, caused a speed reduction per turn of about 0.7km/h compared to course 1. In course 3 where the offset was increased by about 1.5m speed reduction per turn was about 1.0 km/h for both sexes. Increased gate offset in the flat terrain did not lead to any increase in maximal ground reaction force or decrease in minimal turn radii, while the impulse and the subjectively perceived physical load on the athletes were increased with increasing gate offset. The course set intervention had similar effects on women.

CONCLUSION: In flat terrain, the main consequences of increased gate offset are speed reduction and an increased physical load, while minimal turn radius and maximal ground reaction force were not changed. Course setters should consider the trade-off between speed control and physical fatigue when setting courses in flat terrain.

REFERENCES:

[1] Engebretsen, L. et al. 2010. Br J Sport. Med
[2] Gilgien, M. et al. 2014 Br. J. Sports Med.
[3] Spörri, J. et al. 2012 Br. J. Sports Med.
[4] Spörri, J. et al. 2012 Br. J. Sports Med.
[5] Gilgien, J. et al. 2020 Br. J. Sports Med.

AGE-RELATED SKIING TECHNIQUE DIFFERENCES BASED ON QUANTIFIABLE MOVEMENT COMPONENTS

Daniel Debertin[1], Theresa Wirth[1], Lisa Thallmair[1], Peter Federolf[1]

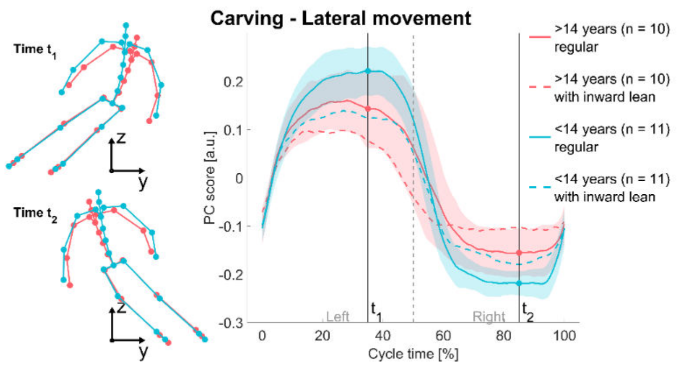
[1] Department of Sport Science, University of Innsbruck, Innsbruck, Austria

Keywords: alpine skiing, technique analysis, inertial measurement unit, principal components

INTRODUCTION: Alpine skiing is a popular sport across various generations; however, it places high demands on the motor control system and requires refined technical skills [1]. Particularly in ski racing, the technique, i.e. the coordination of different movement actions of the whole body, is considered a major factor influencing performance and competitive outcomes [2]. Technique develops with increasing age as external (e.g. ski length and side cut) and internal (e.g. body height, strength, training and competition experiences) parameters and boundary conditions change. In the authors' opinion, age-related changes in skiing technique haven't received in-depth scientific attention so far. The objective of the current study was to analyze age-related skiing technique differences.

METHODS: Full body kinematic data of 11 younger (U14 age group, 12.5±0.5 years, 4 female, 7 male) and 10 older (U16 and U18 age group, 15.4±1.1 years, 2 female, 8 male) junior ski racers were recorded by the Xsens Link IMU system (Xsens, Enschede, NL; 240Hz) on slope. Participants skied their usual race carving technique, and, for reference, were also asked to ski with specific technique variations (pronounced backward, forward, inward lean and inward upper body rotation). Technique elements were quantified using a principal component analysis (PCA)-based approach [3,4]. Independent sample t-tests ($\alpha = .05$) were conducted on technique element characteristics (PC waveforms) to identify significant age-related differences.

RESULTS/DISCUSSION: Skiing technique differed significantly in the amplitude of the lateral movement component between groups ($t(19) = 3.76$, $p = .001$, $d = 1.64$). Younger athletes tended to a greater hip angulation (higher amplitude), whereas older athletes skied with greater inward lean (lower amplitude). Vertical movement amplitude was greater for younger athletes as well ($t(19) = 2.17$, $p = .043$, $d = 0.95$), whereas sagittal (forward and backward lean) and upper body rotational movements were indistinguishable. Lower amplitudes in older athletes suggest that they have optimized their skiing technique to limit their effort. Their reduced hip angulation might imply greater relative strength and a reduced need to compensate.



CONCLUSION: Significant and interpretable technique differences between age groups were observed, which at least in part might stem from different physical prerequisites and acquired skills. Athletes and coaches should consider age as a factor affecting ski racing technique.

REFERENCES:
[1] Hébert-Losier, K et al, 2014 Sports Med
[2] Reid, R, 2010
[3] Federolf, P et al, 2012 Scand J Med Sci Sports
[4] Debertin, D et al, 2024 Scand J Med Sci Sports

AN EMG COMPARISON OF TELEMARK AND ALPINE SKI TURNS

John Seifert [1], Tyler Holmes [1], Toby Hambleton [1], Tom Koto [2]

[1] Dept. of Food Systems, Nutrition, & Kinesiology, Montana State University, Bozeman, MT, USA; [2] Bogus Basin Ski Area, Boise, ID, USA

Keywords: EMG; Telemark Skiing

INTRODUCTION: There have been many technical and mechanical changes to telemark skiing equipment in the last decade. Boots are now produced with stiffer plastic, boot cuffs are higher on the skier's legs, and binding mechanics have improved. These changes allow for better force transmission from skier to ski and for the skier to maintain a more upright body position compared to the traditional deep knee and hip flexions while turning. There are similarities between telemark (TM) and alpine (AL) ski turns, these include: parallel turns, a rotary component to the turn, and vertical unloading of skis to facilitate weight change from ski to ski [1]. However, do these technical similarities translate into similar muscle activity patterns where the telemark turn becomes more like the alpine turn? The purpose of this study was to compare the EMG responses between alpine and telemark ski turns in top level ski instructors.

METHODS: Nine top level, fully certified ski instructors in both AL and TM instruction (1 female, 9 males), completed one run on their AL equipment and one run on their TM equipment. Each run consisted of 28 standardized turns on a groomed, intermediate-level run. Ski radius was similar between AL and TM skis for each skier. EMG was collected on bicep femoris (BF), rectus femoris (RF), gluteus medius (GM), and vastus lateralis (VL). RMS was calculated and all data were time normalized (Delsys, Inc). Turns were divided into 4 phases according to Kröll et al. [2].

RESULTS/DISCUSSION: For the outside leg, the main effect of technique was significant where mean BF activity was greater in AL than TM (0.019 ±.01 vs. 0.0108 ±.005 mV). No other muscular differences between AL and TM were observed for the outside leg. For the inside leg, BF activity was greater during TM than AL (0.015 ±.006 vs. 0.0111 ±.006 mV) while RF activity of the inside leg was greater for AL than TM (0.0189 ±.01 vs. 0.0149 ±.006 mV). No other EMG differences were observed between AL and TM for the inside leg. Mean turn time was faster for AL than TM (2.1 ±.2 s vs. 2.4 ±.3 s).

CONCLUSIONS: The prolonged vertical movement patterns during TM resulted in significantly slower turn times. Muscle activity patterns were generally similar between AL and TM for the outside turning leg especially for the knee extensors. Apparently, the BF is used to a greater extent during AL to stabilize the outside knee and hip. As BF is also an external rotator of the hip and knee, the inside leg may be used to assist turning during TM by adding to the rotary component. To gain further insights into TM turn technique, it is recommended to utilize single subject design to gain more robust data while minimizing intersubject variability.

REFERENCES:

[1] Aschenbrenner, P et al., 2023 Sensors
[2] Kröll, J et al., 2016 BJSM

THE INFLUENCE OF TRUNK IMPAIRMENT LEVEL ON TRUNK MOVEMENT DURING PARA-ALPINE SIT-SKIING

*Yusuke Ishige *[1], Yuki Inaba [1], Noriko Hakamada [1],Akio Kobayashi [2], Shinsuke Yoshioka [3]*

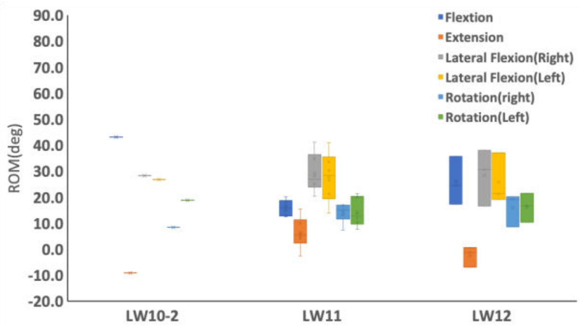
[1] Japan Institute of Sports Sciences, Tokyo, Japan [2] Shiraniwa Hospital, Ikoma-city, Japan; [3] The University of Tokyo, Tokyo, Japan

Keywords: Para-Alpine Sit-Skiing, Trunk Movement, Impairment Level

INTRODUCTION: In recent years, The International Paralympic Committee(IPC) has recommended evidence-based classification [1]. Some studies have examined the evidence for classification of several summer sports. However, very few studies have examined the evidence for classification in para-alpine skiing [2]. It is thought that the reason for this is that it is extremely difficult to quantitatively evaluate how much the limitation of physical activity due to impairment affects ski performance and that the measurement itself on the snow is very difficult to conduct. This study aimed to examine the relationship between trunk impairment level and trunk movement during alpine sit-skiing. The knowledge obtained in this study is considered useful for evidence-based classifications.

METHODS: Ten sit-skiers (six men and four women), including four Paralympic medalists from the National Paralympic Alpine Ski Team, participated in the present study. They were classified as LW10-2(one skier), LW11(six skiers), LW-12-1(one skier), LW12-2(two skiers), respectively. A motion capture method with inertial measurement units was used to measure the kinematics of the skier (Trunk Extension/Flexion, Trunk Lateral flexion, and Trunk Rotation) during slalom free skiing[3].

RESULTS/DISCUSSION: There was no difference between the classes in the range of motion of the trunk during skiing. The trunk lateral flexion angle was associated with centrifugal force regardless of class. Factors other than the range of motion of the trunk may affect turn performance on snow. In this study, skiers free skied on slalom skis. Then, if you ski at the actual gate, there is a possibility that the result will be different. The population of alpine sit-skiers was quite small and a large number of sit-skiers with the same skill and impairment level could not be evaluated. International collaborative research is needed to increase the number of subjects.



The boxplot of the range of motion of the trunk on snow. The circles indicate the values for each subject, whereas crosses indicate the mean values.

CONCLUSION: During the turn, the body is passively moved because of the centrifugal force acting on it. The ROM of the trunk on snow was independent of the degree of disability.

REFERENCES:

[1] Tweedy, S. M. et al, 2011 Br. J. Sports Med.
[2] Stalin, A. et al, 2021 J. Sports Sci.
[3] Ishige, Y. et al, 2022 J. Sports Sci. Med.

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