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BOOK OF ABSTRACTS

Swedish Winter Sports Research Centre
NVC Conference 2017

*“Performance in snow sports:
Translating science into practice”*

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National Alpine Skiing Centre, Åre, Sweden



Photo: Klas Rockberg/SSF

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Foreword

When I took over from Professor H-C Holmberg as director of the Swedish Winter Sports Research Centre (Nationellt vintersportcentrum, NVC) in 2016, I knew that I had very large shoes to fill. This was and continues to be a daunting challenge, but with the challenge comes opportunity and possibility.

One of the first things I did as director of the NVC, together with input from my colleagues, was to define what I feel we are about and want to achieve. This is the definition we work to today:

**“WORLD-CLASS PERFORMANCE AND AN ACTIVE LIFE FOR ALL,
ACROSS THE JÄMTLAND-HÄRJEDALEN REGION AND BEYOND,
THROUGH HIGH-QUALITY RESEARCH, TESTING AND EDUCATION”**

The inaugural NVC conference was set up with a strong focus on education – not only educating via dissemination of our own work and experiences, but equally important to me was for us to be educated, both by other researchers external to the NVC and by coaches, athletes and practitioners working in the field. I was also keen to involve as many international delegates as possible and we were delighted to welcome so many nationalities to Åre over the two days (I counted twelve in total!). Of course, it was also important for us to create a strong regional feeling around this conference and I'm therefore grateful to Åre Ski Stadium and Holiday Club Åre for hosting us – and I'm pleased to have seen so many of you head off up Åreskutan together in your running gear on the Thursday evening!

The specific theme of the NVC conference was chosen with a clear purpose in mind. I believe that developing communication between science and practice is key in elite sport. There is so much passion, expertise, experience and knowledge within our field, yet we still struggle to bridge the gap between science and practice. Projects with elite athletes that successfully provide both relevant and useable information in the field, as well as novel and robust scientific knowledge, are extremely rare. The aim of this NVC conference was to start sharing our experiences and breaking down some of the barriers that we are currently faced with, so that all of us may improve our practice over time.

I am hugely thankful to Dr. Andrew Govus, who worked with us as a post-doc during 2017 and helped immensely with the organisation, logistics and content of this conference. Without his efforts it would not have happened. I am also thankful for the professionalism and enthusiasm of my colleagues at the NVC, who contributed with their diverse experiences and competencies. I am grateful for the support and input of Öyvind Sandbakk and his colleagues at NTNU and Granåsen, as well as Stefan Lindinger and Vesa Linnamo from Austria and Finland, respectively. There were just too many of you to mention everyone individually, but to our colleagues from Sports Tech Research Centre and the Swedish Ski and Biathlon federations, to the coaches, athletes, medical professionals and students, to all of you who came, shared, and learned something, thank you! We are very much looking forward to welcoming you back in 2019 for the 2nd NVC Conference on “Performance in snow sports: Translating science into practice”.

January 2018

Kerry McGawley, director of the Swedish Winter Sports Research Centre

Bringing the Lab to the Field

Why does sport need science?

Kerry McGawley, Ph. D.

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Sport science is a relatively new academic field and has grown enormously in recent decades, particularly in terms of University programs offered, scientific publications and career opportunities. This presentation aims to clarify what sport science is, why it may be useful, how it can be implemented in practice and who are the people responsible for driving it forward. In traditional terms, sport science involves topics such as physiology, biomechanics and psychology. A more comprehensive description may also include strength and conditioning, nutrition, performance analysis, lifestyle management, etc. Nations investing more heavily in sport science at an elite level in terms of infrastructure and expertise (such as Great Britain and Australia, for example) have received significant international sporting success.

While these sport-science institute models are certainly not perfect, they signal a strong relationship between financial investment in elite sport and ranking at an international level. A typical method for implementing sport science is via a sport scientist or practitioner, an individual (or ideally a team of individuals) who is able to understand and interpret often complex science-based principles and communicate them clearly and effectively to coaches and athletes.

Our aim is to improve sports performance by informing practice using the most up-to-date evidence available. This relationship between science and applied sport is key, but is challenging for all parties (i.e., the researchers, practitioners, coaches and athletes). Like all relationships, it requires commitment and effort from all involved and in particular, understanding regarding each other's different needs, priorities, strengths and limitations.

How to use inertial sensors for efficient coaching feedback

Benedikt Fasel, Ph. D.

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In research, inertial sensors are now used for over thirty years. They were first used for gait analysis and thereafter applied to movement analysis in sports. Inertial sensors are especially well suited to a temporal analysis of the movement (e.g. event detection or coordination and symmetry analysis). Other information such as a measure of orientation, speed, or position needs to be obtained from the measured angular velocity and acceleration and has thus a reduced accuracy and precision.

For all applications, dedicated and sport-specific algorithms need to be developed and validated prior to wider use in the field, for example for coaching. The past decades' experiences of the laboratory of movement analysis and measurement has demonstrated that a measurement system will have the highest chances of acceptance by the coaches if it is developed in close collaboration with the coaches. It is important to integrate them into all phases of the project, from the design phase up to the validation and implementation phase. We as researchers need the coaches' input on which parameters are pertinent, how to display the data in the most intuitive way possible, and how to ensure an easy handling of the system in the field.

Advantages of drafting in double poling cross-country skiing

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Background and Aim

In view of the fact that more and more cross-country ski competitions are carried out with mass start, it has high relevance to examine how much force and energy cross-country skiers can save by drafting. Thus, the aim of this project was to investigate the importance of drafting and air drag in double poling cross-country skiing.

Methods

8-10 skiers of each gender, competing on international level, are participating in the study carried out in the wind tunnel at Sports Tech Research Centre, Mid Sweden University. Two skiers are roller skiing at the same time on a very large treadmill, one skier in the front and the other skier behind (drafting), using the double poling technique on low to high speeds ranging from 3 to 6 m/s for females and from 4 to 7 m/s for males. When this is done, the two skiers change places and the same protocol is repeated. The head-wind is set according to skiing speed, simulating natural conditions. Both skiers are measured simultaneously, where dependent variables are oxygen uptake ($\dot{V}O_2$), respiratory exchange ratio (RER), efficiency and propulsive force from ski poles. The air drag for both positions, front and drafting, is calculated from the difference between propulsive forces in the ski poles minus the roller skis rolling resistance.

Results

The study is still in progress, therefore the full results are not available yet. Figure 1 shows, however, an example from one subject how $\dot{V}O_2$ is influenced by the skiing position and speed.

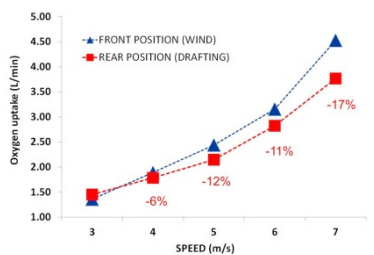


Figure 1. Oxygen uptake in front and rear position at different skiing speeds

Conclusion and Practical Application

It is clear that drafting in double poling has a huge positive influence on skiing economy. How this will be seen in the cycle characteristics and force production will be analyzed soon. This will give new insights for tactical perspectives and may also influence how the training on treadmill when simulating natural skiing should be conducted.

Optimising Athlete Preparation

Optimising recovery in snow sports

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Effective training involves managing physiological and psychological stress to support training-induced adaptations and competitive performance. Recovery from training and competition is a complex process and there is limited evidence to support the use of various commonly used recovery techniques. The foundation of post-exercise recovery is to restore energy, fluid and protein balance although specific recovery techniques may be necessary to reduce the negative impacts of delayed onset muscle soreness following high-intensity sessions or after competition.

Accordingly, recovery techniques can be classified as essential (i.e. those that can be used in all training phases) or supplementary (i.e. those that should be used after high-intensity sessions or during the competition phase). Additionally, the purpose of the current training phase may warrant the use of different recovery techniques. For example, less recovery techniques may be needed during the early phase of the training season when the main outcome is to promote training adaptations, whereas more recovery methods are needed during the competition phase when main outcome is to ensure the athlete is sufficiently recovered to perform optimally.

In the context of optimising post-exercise recovery, sport scientist and coaches can work collaboratively to design individualised post-exercise recovery strategies to ensure athlete can recover effectively from training and competition.

The effect of fatigue on choice of technique and physiological response in cross-country skiing

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Background and aim

Cross-country skiing in hilly terrain elicits use of different sub-techniques. Both the choice of technique as well as fatigue in competition may affect the physiological response. Therefore, the effect of fatigue under variable terrain conditions with free choice of technique is multidimensional given the complex interaction of terrain (incline), skiing speed, technique, and physiological response. Here, we studied how fatigue influenced technique choice and physiological responses during variable incline and speed conditions, but at constant external work rate.

Methods

Eight well-trained athletes performed a 21-minute treadmill roller skiing protocol at 200 Watts, before (PRE) and after (POST) exhaustive skiing (by an incremental protocol). During the PRE and POST protocol, incline was both increased and decreased by 1% each minute (3% - 11% - 3%), while speed was altered accordingly to maintain the constant workload. The choice of technique, VO_2 , RER, and heart rate were recorded continuously. ANOVA for repeated measures was used for statistical analysis.

Results

Technique choice and cycle rate were hardly affected by fatigue. After fatigue, an enhanced VO_2 was obtained during the first 6 minutes, with heart rate remaining elevated (by ~10 bpm) during the entire protocol after fatigue. RER was reduced during the entire POST protocol.

Conclusion

The fatigue induced a lasting enhanced physiological response, but metabolic cost returned to fresh state levels. In combination with unaltered choice of technique and cycle rate, this indicates that technical execution is unaffected.

Effects of rifle carriage in biathlon

– A physiological and biomechanical perspective

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Biathlon combines cross country skiing and rifle marksmanship and during a race, the athletes need to carry their rifle (minimum weight 3.5 kg) at their back the whole time. When carrying a rifle, the athlete is increasing oxygen uptake, ventilation, respiratory equivalent, heart rate and blood lactate during rollerskiing at the same speed both with and without rifle^{1, 2}.

From a biomechanical perspective, the biathlete is decreasing cycle length, peak leg force and average cycle force while increasing cycle rate when skiing with the rifle on¹. Pilot testing in field (on snow) by Jonsson & Laaksonen have shown trends that range of motion in flexion/extension of hip, knee and shoulder are decreased and a tendency to an increased pressure on the innerpart of the foot when skiing with rifle.

When carrying the rifle, athletes also seem to change their distribution of different gears by increasing their use of gear 2 while decreasing the use of gear 3, and the amount of changes during the race is bigger.

In total it seems like the rifle carriage is effecting the female athletes more than the male, which may be a result of a higher relative load of the rifle (compared to bodyweight) for the female biathletes. Rifle carriage is effecting the skiing both from a physiological and a biomechanical perspective, and more research is needed in the area to be able to optimise the sport specific training (eg. technique training, strength and stability training, physiological training zones).

1. Stoggl, T., et al., *Effect of carrying a rifle on physiology and biomechanical responses in biathletes*. Med Sci Sports Exerc, 2015. 47(3): p. 617-24.
2. Rundell, K.W. and L. Szmedra, *Energy cost of rifle carriage in biathlon skiing*. Med Sci Sports Exerc, 1998. 30(4): p. 570-6.

Maintaining Athlete Health

Understanding "ski asthma": risk factors and management strategies

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Asthma and exercise-induced bronchoconstriction (EIB) are common in high-level athletes and especially prevalent in cross-country ski athletes. In a recent online questionnaire distributed to high level Swedish cross-country skiers, 29% of adolescent athletes (age 15-19) and 35% of senior athletes self-reported physician-diagnosed asthma. Cross-country skiing has been identified as an independent risk factor for development of EIB. It is hypothesised that a combination of the cold and dry climate, high ventilation rates, training frequency and duration may contribute to airway inflammation and trigger bronchoconstriction during or shortly after exercise.

Alongside pharmacological management, there may be strategies that athletes and coaches can utilise to manage asthma or EIB. Several studies suggest that warm up routines containing short bouts of high-intensity exercise may offer protection against subsequent EIB, termed a 'refractory period'.

In cross-country skiers, refractoriness was observed in around a third of athletes in a small cohort. Other athletes may display a gradual, progressive EIB; whether these athletes also respond to high-intensity warm-up warrants further investigation.

Heat-exchanger masks have been shown to reduce the severity of EIB substantially in athletes with mild to severe EIB in cold conditions (-15°C to -25°C).

It is recommended that athletes with asthma/EIB explore the efficacy of high-intensity warm-up regimes on airway responses and utilise heat exchanger masks, especially on the coldest days.

Using Research to Inform Training in Skiing

Optimising the knowledge translation between research and practice in elite sport

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In this talk, I will share my personal experiences of success factors and possible pitfalls in the knowledge translation between research and practice in elite sport. With a background as an elite cross-country skier and with coaching-experience of skiers on a high international level, I had a relatively good point of departure for beginning my research career in the applied field with a Ph.D. focused on cross-country skiing. There was already a common respect between the athletes, their coaches and me. I knew the “tribal language” and had a continuous dialogue on what type of knowledge would be of interest to the coaches. This dialogue provided the basis for my research questions and allowed a relatively easy access to perform high-quality research on world-class athletes. At the same time, my supervisors and research colleagues had a different, but complementary, view on the same questions, a quality that assured the process from a scientific point of view.

My first studies focused on the physiology of sprint skiing, where main coach of the national team, Ulf Morten Aune, allowed me to perform multiple experiments on his successful team. World- and Olympic champion Tor-Arne Hetland, was my main pilot tester and discussion partner. This process provided practical relevance, whereas scientific quality was assured by my supervisors Professor Gertjan Ettema and Professor H-C Holmberg. Indeed, the combination of working closely with some of the best coaches and athletes and world-leading scientists was a unique advantage for my learning process.

Different challenges occurred later in my research career, when I worked with other types of sports where I lacked the practical understanding and did not have the natural intuition about the sport. In such cases, the process resulted in the best “working climate” when it was facilitated by another person, a “translator” who understood the sport well and worked closely with coaches and athletes on a daily basis. Awareness of my own role and a common respect for the different points of departure were key factors for success, and has helped us to avoid stepping into pitfalls on this journey.

In order to further reinforce the success factors for combining high quality research with world-class athlete support, we moved our own research centre to the top sport facilities in Granåsen, where we share the location with employees of Olympiatoppen and are close to the athletes’ natural training arena. We believe that the common lunch area is the most important room in the house, since this is where common respect and understanding is built between researchers and coaches/athletes in a friendly environment. Here, we designed new experiments together and knowledge is implemented through an ongoing dialogue at the training arena, in the laboratory and in the lunch area. In addition, we have prioritized communication through coach education programs, coach education literature and popular science papers, which has been of importance in this context.

As researchers we must pay close attention to the practically based knowledge of coaches and athletes, which is often ahead of what current research can prove. Many of their ideas and comments have led to new hypotheses, and many of their questions could not be answered at that point. Thus, the questions were highly relevant, so-called research GAPS that sometimes were developed into high quality scientific studies. This process should be a two-way process of “knowledge translation” where practical and scientifically based knowledge are regarded complementary.

Laboratory-based factors predicting skiing performance in biathlon

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Maximal oxygen uptake ($\dot{V}O_{2\max}$), $\dot{V}O_2$ at lactate threshold ($\dot{V}O_{2\text{-LT}}$), and gross efficiency (GE) are the three main factors determining endurance performance. The purpose of this study was to evaluate the association between laboratory-based measures and skiing performance in biathlon.

Twenty-eight Swedish biathletes competing both at national and international levels performed a submaximal incremental test followed by a maximal time-trial (TT) prior to the start of the 2016-17 season. Treadmill roller-skiing was used for testing and $\dot{V}O_{2\max}$, $\dot{V}O_{2\text{-LT}}$, GE, and aerobic (AeMR) and anaerobic (AnMR) metabolic rates, were calculated.

All participants competed in a same biathlon competition (BC) within two months of testing. TT and BC skiing performance were significantly correlated in both sexes. $\dot{V}O_{2\max}$ was related to TT and BC skiing performance for the females but not the males, while $\dot{V}O_{2\text{-LT}}$ was not associated to TT or BC skiing performances. GE was correlated with BC skiing performance in both sexes but with TT skiing performance only for the males. AeMR was correlated with TT time in the females, while AnMR was not related to TT or BC times for either sex.

GE, AeMR and AnMR explained 99% of TT skiing performance in both sexes. Anaerobic energy contribution, $\dot{V}O_{2\max}$ and GE explained 67% and 52% of the BC skiing performance for females and males, respectively. Therefore, different physiological variables explain the laboratory-based TT test in females and males. Moreover, the TT test appears to effectively predict field-based skiing performance in biathlon. Finally, $\dot{V}O_{2\text{-LT}}$ and GE appear important for biathlon skiing performance.

The importance of gross efficiency and pacing strategies in cross-country skiing

Erik Andersson

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Performance in endurance sports is associated with the maximal aerobic metabolic rate (i.e., $\dot{V}O_{2\max}$)⁽¹⁾, whereas the importance of anaerobic energy supply is considered to be lower and decreases with prolonged exercise duration. In addition, the efficacy of converting metabolic energy to external work (i.e., gross efficiency, GE) is an important performance factor⁽¹⁾.

Recent findings by Andersson et al.⁽²⁾ suggest GE as the most discriminating performance factor in a group of well-trained cross-country skiers. Results in cycling indicate a decline in GE during supramaximal exercise⁽³⁾, which also might be the case in cross-country skiing.

Cross-country skiing is performed over undulating terrain and involves several different sub-techniques⁽²⁾, which may have a direct effect on how athletes distribute their energetic resources during a race⁽⁴⁾.

When modeling endurance performance in cross-country skiing and road cycling, a varying exercise intensity with higher work rates on the uphill sections has been shown to improve

performance compared with even exercise intensities⁽⁵⁾. In connection with sprint roller-skiing, a fast start with declining speed (i.e., positive pacing) is typically used⁽⁴⁾. The benefits of positive pacing may, in part, be related to faster $\dot{V}O_2$ kinetics⁽⁴⁾.

- 1) Joyner & Coyle (2008). *J Physiol* 586(1), 35-44.
- 2) Andersson et al. (2017). *Scand J Med Sci Sports* 27(4), 385-398.
- 3) Noordhof et al. (2015). *Int J Sports Physiol Perform* 10(1), 64-70.
- 4) Andersson et al. (2016). *Med Sci Sports Exerc* 48(12), 2544-2554.
- 5) Sundström (2016). Doctoral thesis.

How fast are cross-country skiers in the finish-sprint during a sprint competition?

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Background and Aim

The finish-sprint of sprint cross-country (XC) skiing competitions requires high maximal speed (\dot{V}_{\max}) as well the ability to utilize a high fraction of V_{\max} at the end of a race. However, the latter ability may be influenced by skiing techniques and pacing strategy. The aim of this study was to investigate the $\% \dot{V}_{\max}$ obtained in the finish-sprint of XC sprint competitions in classical and skating XC skiing, as well as the effect of different pacing strategies on this ability.

Methods

Twelve elite male Norwegian XC skiers (21.3±2.1 years, $\dot{V}O_{2\max}$ 71.4±3.7 ml·kg⁻¹·min⁻¹) performed 80-m \dot{V}_{\max} tests on flat terrain using the classic (double poling) and skating (G3) techniques, followed by two 1.4-km sprint time-trials with positive vs. conservative pacing strategies in both styles, ended with a finish-sprint during the last 80-m (i.e. the same section as the \dot{V}_{\max} test).

Results

The skiers achieved 83±6 and 84±5 of their \dot{V}_{\max} with positive pacing, while 86±6 and 87±5 were achieved when pacing conservatively, for classic and skating style, respectively. $\% \dot{V}_{\max}$ was higher with conservative pacing in classic ($P < 0.05$), with only a trend revealed for skating.

Conclusion and Practical Application

An elite XC skier obtains approximately 83-87% of \dot{V}_{\max} in the finish-sprint during a sprint race, with the $\% \dot{V}_{\max}$ achieved in the finish-sprint being positively influenced by conservative pacing. Hence, a skier who is able to combine a high \dot{V}_{\max} with the ability to enter the finish-sprint with low levels of fatigue will improve the chances to win the race.

Technology in Snow Sports

Aerodynamic drag in alpine skiing

Ola Elfmark

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This is based on my master thesis on modelling of aerodynamic drag in alpine skiing at NTNU, carried out during the spring semester of 2017. My supervisor at NTNU was Lars Sørtrå and Lars Morten Bardal and the project was carried out for the Norwegian ski federation under the supervision of Robert Reid. The presentation preference is oral.

Abstract

Most of the resistive force in the alpine skiing speed disciplines is caused by aerodynamic drag, and a better knowledge of the drag force is therefore desirable. In this study a database of drag area (CDA) values, for a range of body positions commonly used in alpine skiing, was made from wind tunnel measurements. From this a numerical model for the aerodynamic drag was made. The model was validated with an uncertainty of 3%.

In order to calculate the drag coefficient (CD), a method for calculating the frontal area of an alpine skier inside a wind tunnel was used with an uncertainty of 0.012 m². The general model for aerodynamic drag was based on a set of measurements from one female alpine skier from the Norwegian Ski Federation (NSF). In order to make the model universally applicable, by correcting for various body size and shape, an investigation of individual adjustments of the model was made, based on wind tunnel measurements of four, male alpine skiers from the NSF. The results showed only small variations in the drag coefficient between the different subjects, and a comparable percentage change of CDA between two tested reference positions.

Thereby the frontal area in a reference position was considered to be a suitable scaling variable for individual adjustments of the model. Validations showed an uncertainty of 3% for the individually adjusted model. The model developed can be a valuable tool for performance analysis in alpine skiing when combined with a motion tracking system.

Towards automated evaluation of posture quality and its relation to performance

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Background

Despite the evident upsurge of Artificial Intelligence (AI) applications in different contexts, the use of AI-based tools particularly in the biomechanical analysis of skiing techniques is scarce, e.g. [3, 5].

Aim and main research question

The aim of this research is to develop AI-based methods for: 1) providing instant feedback to the skier regarding her/his own technique execution; and 2) supporting coaches with statistical information about biomechanical features of the skier. The main research question relates to how AI-based methods can be used for automatically evaluate posture quality in double poling (DP).

Methods

Data was collected by letting two skiers choose the roller ski treadmill speed (submaximal intensity), focused on DP quality execution. Two sessions data were collected using a portable 3D camera and AI learning algorithms were applied on the dataset. The case study was used as a pilot evaluation study of the methodology.

Preliminary results and future work

Our AI platform was able to infer automatically DP cycles: poling phase (PP) and a recovery phase (RP) (algorithm false positives: 2.28%, true positives: 97.32%), analyzing different body limb angles. Real-time visual feedback was found valuable for reflecting about technique by both skiers and an experienced coach. Given the size of the pilot study, correlations among physiological and biomechanical measurements were not analyzed. However, limb angles in PP and RP were found similar to previous findings in DP literature [2]. Real-time visual feedback has been found influential in training [1, 4]; a game-like interface for selflearning/assessment is being developed. A larger study will be performed in near future.

REFERENCES

- [1] H. P. Crowell, C. E. Milner, J. Hamill, and I. S. Davis. Reducing impact loading during running with the use of real-time visual feedback. *Journal of orthopaedic & sports physical therapy*, 40(4):206-213, 2010.
- [2] H.-C. Holmberg, S. Lindinger, T. Stöggl, E. Eitzlmair, and E. Müller. Biomechanical analysis of double poling in elite cross-country skiers. *Med Sci Sports Exerc*, 37(5):807-818, 2005.
- [3] A. Holst and A. Jonasson. Classification of movement patterns in skiing. In SCAI, pages 115-124, 2013.
- [4] S. P. Messier and K. J. Cirillo. Effects of a verbal and visual feedback system on running technique, perceived exertion and running economy in female novice runners. *Journal of sports sciences*, 7(2):113-126, 1989.
- [5] T. Stöggl, A. Holst, A. Jonasson, E. Andersson, T. Wunsch, C. Norström, and H.-C. Holmberg. Automatic classification of the sub-techniques (gears) used in cross-country ski skating employing a mobile phone. *Sensors*, 14(11):20589-20601, 2014.

Winter Parasport

What can we learn from paraskiing?

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Parasport in general has developed a lot the last decades and there is a trend in the western world to integrate athletes with impairment into “ordinary” sports. Norway is a precursor of the integration process. In the evaluation of the Norwegian integration process from 2006^[1] it was reported that “all organizations reported improved attitudes toward individuals with a disability and indicated that integration was a demanding enterprise”.

Within paraskiing (cross-country skiing, biathlon and alpine skiing) athletes with several different impairments participate, such as: amputation, spinal cord injuries, cerebral palsy, visual impairment and intellectual impairment. Athletes with impairments have special needs regarding training and preparation for competitions. A review^[2] about influences on development of athletes with disabilities states that para-athletes need coaches to structure training, give feedback and prevent injuries. The coaches also need competence regarding the impairment and the related special needs. In general, there is a need for more research regarding this, but this presentation summarize some of the available research^[3, 4].

As an overview, athletes with amputation need to cope with asymmetry and therefore need more strength training. Athletes with visual impairments need more training regarding balance, coordination and maybe posture. Athletes with spinal cord injuries can have, depending on the level of injury, a positive effect from respiratory muscle training. These athletes also have impaired hemodynamics, and might have reduced maximal heart rate and trouble with cold temperatures. Athletes using wheelchairs have increased risk of infections, shoulder injuries and pressure sores. For athletes with cerebral palsy, spasticity is common. There are several methods used to cope with and reduce spasticity such as finding a functional movement, performing a special warm-up, handling environmental stressors and in some cases stretching. Athletes with intellectual impairment have harder to manage stressors and can be more anxious before competitions and more sensitive to distractions. This group of athletes have shown positive effects from psychological training skills program.

In the end, all athletes have individual needs, no matter if the athletes have an impairment or not. What is really the difference between a special need and an individual need?

1. Sørensen, M, Kahrs, N. Integration of disability sport in the Norwegian sport organizations: Lessons learned. Adapted Physical Activity Quarterly, 2006 23(2), 184-202.
2. Dehghansai, N, Lemez, S, Wattie, N, Baker, J. A systematic review of influences on development of athletes with disabilities. Adapted Physical Activity Quarterly, 2017 34(1), 72-90.
3. Tweedy, Sean, et al. The paralympic athlete: handbook of sports medicine and science. 2011.
4. Vanlandewijck, Yves C. Training and Coaching the Paralympic Athlete. John Wiley & Sons, 2016.

Technology in paraskiing

– Experiences from development of a sit-ski and a lower leg prosthesis for Nordic skiing

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Sports and recreational equipment for people with a disability is a prerequisite for health and inclusion through physical activity, sports and outdoors activities. The accessibility of equipment is very low on the global level and therefore it is an international societal challenge.

The objective of this work is to provide the engineering society with an understanding of factors influencing the equipment development for parasports, from grass-roots to elite level.

The methodology of this work has primarily been the authors' evaluations of own experiences of equipment development in parasports in relation to references and discussions thereof. Two equipment products were exemplified and parameters in relation to their development were summarised.

The results showed that the meaning of "fair and equal" for elite level equipment was not understood early in the product development process, which led to a technological dispute and the rejection of the lower leg prosthesis for Nordic skiing skate technique for competing on the Paralympic level. The cross-country sit-ski, that was developed more for the leisure market, had a greater balance in the demands from different stakeholders.

In conclusion, it was suggested to invite sport equipment stakeholders to share values and requirements early in the equipment design process. Functional products and modular equipment, primarily for the leisure market, were encouraged for future access to and development of low-cost equipment on a global level. A multi-disciplinary technology collaboration platform and engineering design guidelines were suggested for technology clarification and the development of fair, safe and universal equipment design.

Endurance performance in Paralympic

sitting sports – testing and training

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In endurance sports, three factors mainly play a role for endurance performance: 1) maximal oxygen uptake ($\dot{V}O_{2max}$), 2) the % of $\dot{V}O_{2max}$ used at the anaerobic threshold (ANT) and 3) efficiency^[1]. In athletes with a disability, who exercise in an upper-body mode, $\dot{V}O_{2max}$ is rarely reached and peak oxygen uptake ($\dot{V}O_{2peak}$) is used instead. This is in part due to the upper-body mode itself that activates a relatively low muscle mass and consequently does not fully tax the cardio-respiratory system. Furthermore, the impact of an individual's disability on movement function and physiological capacity reduces $\dot{V}O_{2peak}$. In our research, we found that as compared to a group of similarly upper-body trained able-bodied controls, $\dot{V}O_{2peak}$ values in a group of Paralympic sitting athletes who mostly had spinal cord injuries are lower due to their disability-related limitations (45 ± 6 vs 35 ± 7 mL·kg⁻¹·min⁻¹, respectively). This is likely related to blood pooling in the legs and the abdomen, autonomic dysfunction and a negative long-term effect of exercising with a limited muscle mass on cardiovascular function^[2,3].

In a systematic literature review and meta-analysis, we analyzed the influence of training and competing in different sitting sports, as well as the influence of sex, age, type of disability, test

mode and body mass on $\dot{V}O_{2peak}$. This was done by summarizing the data of 57 studies including 771 athletes with different disabilities in 14 different sitting sports. The highest $\dot{V}O_{2peak}$ values were found in Nordic sit skiing (45.6 ± 5.1 mL·kg⁻¹·min⁻¹), an endurance sport with continuously high physical efforts, and the lowest values in shooting (17.3 ± 3.5 mL·kg⁻¹·min⁻¹), a sport with low levels of displacement, and in wheelchair rugby (18.9 ± 1.5 mL·kg⁻¹·min⁻¹) where mainly athletes with tetraplegia compete. The regression analyses showed that being a man, having an amputation, not being tetraplegic, testing in a wheelchair ergometer and treadmill mode, as well as having high or low body-mass, respectively, were found to be favorable for high absolute and body-mass normalized $\dot{V}O_{2peak}$ values.

In a sports context, specificity of the movement mode is important in reaching $\dot{V}O_{2peak}$ and exercise efficiency that are reflective of the aerobic demands of the respective sport. For ice sledge hockey players as well as sitting Para cross-country skiers and biathletes, upper-body poling is the most sport-specific exercise mode. Thus, we investigated the test-retest reliability of upper-body poling $\dot{V}O_{2peak}$ tests of different duration. Whereas both the 3-min and the incremental test display high relative reliability (ICC_{2,1} 0.942 vs 0.933, respectively), the incremental test induces slightly higher $\dot{V}O_{2peak}$ (44.5 ± 5.5 vs 45.4 ± 5.5 mL·kg⁻¹·min⁻¹, respectively). However, the 3-min test seems to be more stable with respect to absolute day-to-day differences in $\dot{V}O_{2peak}$. Therefore, the choice between the 3-min and the incremental test depends on whether the design of a study requires the most reliable test or the highest peak responses. Furthermore, we compared $\dot{V}O_{2peak}$ and exercise efficiency in upper-body poling to arm crank ergometry, which is the mode most commonly used in upper-body exercise testing. When the upper-body was restricted, $\dot{V}O_{2peak}$ was not significantly different in upper-body poling as compared to arm crank ergometry (36.0 ± 7.8 and 37.3 ± 7.0 mL·kg⁻¹·min⁻¹, respectively, $p=0.112$), which occurred despite a lower peak power output in upper-body poling (118 ± 34 and 145 ± 33 W, respectively, $p<0.001$). The 18% lower peak power output can solely be explained the lower exercise efficiency in upper-body poling, since metabolic rate at the same submaximal power outputs was 20% higher in upper-body as compared to ACE ($p<0.001$). However, there was no difference in exercise efficiency between PARA and AB, indicating that disability does not influence exercise efficiency.

To systematically improve cardio-respiratory fitness and sports performance, Paralympic and Olympic athletes employ 3- or 5-zone intensity scales, which are based on the aerobic and anaerobic threshold concepts. However, in Paralympic sitting athletes, who exercise in an upper-body mode, we were not able to confirm the presence of the aerobic and the anaerobic threshold, but rather found a continuous increase in physiological responses with an increase in exercise intensity. Furthermore, we found considerably higher blood lactate responses and lower heart rates at the same subjective exercise intensities in the Paralympic as compared to the Olympic athletes. This is likely due to a combination of exercising in an upper-body mode and the above-mentioned disability-related physiological limitations. Therefore, different concepts for prescribing exercise intensity that take into consideration the different physiological responses might be needed in Paralympic sitting athletes.

1. Joyner MJ, Coyle EF. Endurance exercise performance: the physiology of champions. *J Physiol.* 2008 Jan 01;586(1):35-44.
2. Haisma JA, Bussmann JB, Stam HJ, Sluis TA, Bergen MP, Dallmeijer AJ, et al. Changes in physical capacity during and after inpatient rehabilitation in subjects with a spinal cord injury. *Arch Phys Med Rehabil.* 2006 Jun;87(6):741-8.
3. Theisen D. Cardiovascular determinants of exercise capacity in the Paralympic athlete with spinal cord injury. *Exp Physiol.* 2012 Mar;97(3):319-24.

Performance Assessment and Analysis

Effects of performance level in biathlon-specific shooting tests

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Background and Aim:

Shooting performance is a crucial component for the overall result in biathlon competitions. The knowledge about the effects of various shooting-specific capacities on shooting performance would be of high value for coaches and athletes. Thus, the aim of the current study was to compare biathlon-specific shooting tests between competitive biathletes on different performance levels.

Methods:

17 junior, 9 national-class and 12 world-class biathletes performed 30 shots with their normal competition-specific technique (Normal), 20 shots when aiming along a horizontal line (Line), and one test where they aimed as steady as possible for 30-sec on one target (Hold). All tests were done in the prone and standing position. During Normal, the sighting speed (V05) and trigger pressure 0.5 (P05) and 1.0 (P1.0) sec prior to triggering were calculated. Vertical movement from Line and the radius of the sighting in Hold, were determined. Tests were performed on an indoor 5-m shooting range using the 100-Hz Scattlaser shooter training system.

Results:

The groups with best performance levels (including higher hit rates in competitions) showed lower V05 during prone, and lower V05, less vertical movement in Line and better Hold during standing (all $p < 0.05$). No group differences were found for P05, but the best performing group had higher trigger pressure 1.0s prior to trigger pull ($p < 0.01$), while a trend for performance-level differences in Hold during prone occurred ($p = 0.079$).

Conclusion and Practical Application:

The findings in this study show that biathletes on better performance levels have lower speed on the rifle, better control of the rifle during a holding test and less vertical movement when aiming along a horizontal line.

Analysis of a biathlon sprint competition and associated laboratory determinants of performance

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Background and Aim

Biathlon is a winter-sport combining rifle shooting with crosscountry (XC) skiing using the skating technique. In the present study, we aimed to investigate the contribution of shooting and XC skiing performance to the overall biathlon sprint performance, as well as their relationships to laboratory-measured capacities obtained during treadmill roller skiing.

Methods

Eleven elite male biathletes were tracked by a global positioning system (GPS) device and heart-rate monitor during an international biathlon sprint competition. Within a period of 6 weeks prior to the competition, physiological and kinematic responses during submaximal and maximal roller skiing on a treadmill were determined.

Results

Multiple regression analysis revealed that XC skiing time, shooting performance and shooting time plus range time explained 84%, 14% and 2% of the overall performance, respectively (all $p < 0.01$). Relative heart-rate and rating of perceived exhaustion during submaximal testing, and time-to-exhaustion during incremental roller skiing to exhaustion all correlated significantly with overall biathlon performance, XC skiing performance, as well as performance in different terrains ($r = 0.64-0.95$, all $p < 0.05$).

Conclusion and Practical Application

The present findings show that XC skiing clearly exerts the greatest influence on overall biathlon sprint performance. Furthermore, relatively “easily” measured laboratory capacities such as relative heart-rate and rating of perceived exhaustion during submaximal roller skiing and time-to-exhaustion during incremental treadmill roller skiing can be used to distinguish biathletes on different performance levels and track progress on the development of XC skiing capacity.



Photo: Skidskytte.se

