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Guest editorial

Performance and safety in elite skiing sports: A big challenge on specificity, individuality, and complexity

Winter sports, including those with a focus on gliding with skis on snow, have become extremely complex in the last few decades. During the Olympic Games held in Pyeongchang, Republic of Korea, in 2018, a greater number of different skiing competitions took place: alpine skiing with giant slalom, downhill, slalom, and super-G and alpine combined; biathlon with 10-km sprint, 12.5-km pursuit, 15-km mass start, 20-km individual, and a 4 × 7.5-km relay; cross-country skiing with 6 different kinds of races including short, medium and long distances, classical and skating techniques, and individual and mass start; free-style skiing with aerials, moguls, ski cross, ski halfpipe, and ski slopestyle; Nordic skiing combined with ski jumping on large and normal hills, followed by cross-country skiing over 10 km; and snowboard with big air, half pipe, parallel giant slalom, slope style, and snowboard cross.

Each of these skiing sports is complex and challenging from physical, technical and tactical perspectives. In this special section of the *Journal of Sport and Health Science* (*JSHS*), Stöggl et al. demonstrate the complexity of physiological and biomechanical demands on cross-country skiing disciplines. They describe the wide range of distances that have to be skied using a large variety of different skating and classical skiing techniques such as diagonal stride, double poling, kick double poling, V2 and V1, and various subtechniques. The selection of the various techniques depends on individual preferences with regard to variations in terrain and racing formats (such as individual start, mass start, pursuit, knockout sprint, *etc.*), as well as the effects of equipment like glide or grip wax and external conditions like snow or humidity. In addition, the tactical perspectives used in the individual pacing strategies in an effort to prevent premature fatigue prior to the end of the competition play an important role. The study shows that pacing influences the decisions about which skiing techniques are used during a race. The authors conclude that further improvement in elite performance in cross-country skiing could be achieved through a focus on training for specific techniques to maintain long cycles without compromising cycle rate on different inclines, at different speeds, and under varying external conditions.

Another skiing sport with a high degree of complexity is the biathlon, which combines cross-country skiing with rifle marksmanship. Laaksonen et al. show in their article that, in addition to the physiological and biomechanical demands made on skiers by cross-country skiing techniques, the biathlon puts intense mental pressure on skiers and challenges their fine motor control when they shoot after intense exercise. A biathlon competition consists of 3 or 5 high-intensity bouts of skiing of 5–8 min each followed by a short period of performing the shooting. Biathlon performance is highly influenced by both peripheral and central fatigue. Apart from biomechanical challenges during shooting, such as body sway and rifle stability with a focus on shoulder forces and triggering coordination, the psychophysiological aspects of the sport, such as cardiac and cortical activities, skin conductance, gaze behavior, and breathing technique during shooting, are of great importance.

Apart from complexity and specificity, the greatest challenge in skiing sports is injury risk. Alpine skiing, free-style skiing, and snowboarding are sports with an especially high injury rate.[1] Injury rates of 36.7 per 100 World Cup athletes per season were reported, with the knee being the most frequently affected body part. Additionally, the injury rate at the youth level has been reported to be 0.63 traumatic injuries per athlete per season. The work by Gilgien et al.[1] indicates that the various types of competition in alpine skiing (slalom, super-G, giant slalom, and downhill) are almost equally dangerous per race time unit, but the injury risks are different. In super-G and downhill, injuries seem to be related to high speed and jumps, whereas injuries in slalom and giant slalom are likely related to high loads during bidirectional turning phases. A maximal loading of 3.16 body weight per turn has been calculated. In addition, overuse injuries related to the back have become a severe problem among top alpine ski racers.[2] The mechanisms for this kind of overuse injury seem to be the combined occurrence of frontal bending, lateral bending, and torsion in the highly loaded trunk during turning. These movement and loading patterns create high spinal disc loading. The most frequently suggested way to decrease the injury risk in alpine skiing is to optimize the skiing-specific fitness level. Steidl-Müller et al., in their article in this special issue, hypothesize that a preferential lateralization of the lower limbs might create a high injury risk in alpine ski racing. In their prospective study, they found that limb differences in unilateral leg extension strength represent a significant injury risk factor in

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youth ski racers. This finding highlights the importance of having not only a well-developed, symmetric strength capacity in both legs but also a well-developed core stability.

The most common knee injury in alpine skiing is the anterior cruciate ligament (ACL) rupture.[3] The article by Raschner et al.[4] is thus far the only one that has investigated the relationship between strength and power performance of the legs and the ACL injury risk in alpine ski racers. However, no associations were found between ACL injury prevalence and the tested strength and power parameters. In the article by Jordan et al. in this section, the authors demonstrate that specificity in testing fitness parameters is of high relevance in identifying sport-specific injury risks. Using a dual-force platform, they were able not only to measure overall performance but also specific neuromuscular performance of ski racers during counter movement jump and squat jump. The main finding was that an increased eccentric force and impulse generation occurred in the deceleration phase of the counter movement jump in elite *vs*. adolescent alpine ski racers. Among elite alpine ski racers, this is most likely related to a sport-specific neuromuscular adaptation to the chronic exposure to high-force eccentric muscle loading during turns. The authors suggest monitoring the effectiveness of off-snow fitness training to optimize performance and minimize injury risks, using test systems that are as sport specific as possible.

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