Winter sports topical collection

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The term winter sports encompasses a variety of athletic activities that take place on the snow/ice or in mountainous terrain and that share a common requirement for the equipment used to support the performance, safety, or enjoyment of those taking part. This is the third Winter Sports Topical Collection published in *Sports Engineering*, the first two published ahead of the Sochi [1] and PyeongChang 2018 [2] Winter Olympics. This topical collection will be published ahead of the Beijing 2022 Winter Olympics. The continued calls for winter sports research by *Sports Engineering* demonstrate the journal's support for this important field and the valued contribution that the published research provides. The field is vast and varied which is reflected in the submissions and accepted articles in this collection. In total, eleven articles were accepted and published in the collection covering winter sports such as downhill and cross-country skiing, cross-country sit skiing, ice hockey and speed skating. In this Editorial, we will provide a brief overview of the published articles.

Five of the published articles used wearable sensors or instrumented equipment to provide novel insights into equipment performance or athlete technique. Hermann et al. compared two types of sensors (capacitive and piezoresistive), integrated into base layer compression pants, for measuring knee flexion angles of an artificial leg and of skiers. The capacitive sensors were deemed more accurate and demonstrated less hysteresis. The authors suggested

that these sensors could be used to monitor knee flexion angle and subsequently, be used as one input parameter of a mechatronic ski binding system to adapt the release settings of the binding according to the current risk of knee injury. Bruzzo et al. embedded inertial measurement units (IMUs) into cross-country ski poles to quantify the pole lean angle. The authors validated the IMUs against video data. Pole lean angles and timing variables showed good agreement between IMU and video data. The results provided strong support for the sensors use in measuring future poling performance of cross-country skiers in the field.

In parasport, classifying an athlete's impairment is an important consideration to ensure fairness in competition. Rosso et al. recognised this challenge in cross-country sit skiing and evaluated the reliability of objective trunk strength and control measures for the purpose of classifying athletes. An electronically controlled sledge was instrumented with force sensors and IMUs to quantify strength and balance measures. Maximal voluntary contractions, balance control tests and poling tests, that emulated the pushing phase during double poling, were conducted. Using principal component analysis and k-means clustering techniques, groupings emerged in the strength and balance measures that were proposed to allow the impairment of trunk strength and control to be assessed and used as part of the classification system.

The final two articles in the sensors and instrumentation category, focus on quantifying the mechanical behaviour of downhill skis. Yoneyama et al. used a previously developed measurement system to quantify deflection, pressure, and load for a skier performing carved turns with two skis of different flexural stiffnesses. Changes in flexural stiffness modified the magnitude of deflection, the location of the applied forces, and peak pressures that influenced the ski-snow contact pressure. Gosselin et al. combined instrumented equipment and modelling approaches to measure the bending and torsional deformation shapes associated with a ski's vibration response during partially skidded turns. The combined methods showed good agreement for deflection shape changes and demonstrated that the observed vibration

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was a result of coupling between bending and torsion caused by the ski being on edge.

Two articles used experimental methods to quantify key biomechanical variables. Krumm et al., proposed an alternative approach to using instrumented equipment and aimed to predict push-off forces using pressure insoles and machine learning methods. The authors used an imitation speed skating manoeuvre on a slide board to explore the most suitable predictive machine learning models. Linear multiple regression models were trained and tested to predict the push-off forces and key performance indicators. The agreement between measured and predicted forces varied by individual skater whilst the key performance indicators, such as the time of events, were predicted accurately. Parry et al. compared the effect of a new cross-country roller-ski binding technology to a traditional ski binding on skiers biomechanical, physiological, and performance measures during treadmill roller-skiing. Using motion analysis and a portable gas analyser, key discrete biomechanical variables and cardiovascular measures were recorded when skiers used the two types of roller-ski bindings. The results did not demonstrate a clear benefit of the new binding technology on roller-skiing performance but highlighted the requirement for suitable familiarisation periods when comparing the performance of athletes when using new equipment.

Modelling approaches were considered by four of the published articles. Komissarov published two papers in the collection on the mechanics of sideslipping in alpine skiing. The first considered the theory of machining (or cutting) of snow and ice to help in modelling the dynamics of sideslipping during skiing turns. The model showed good agreement to laboratory experiments, but demonstrated a slight under prediction of the “cutting force” (i.e. force aligned with the surface) proposed in part to the simplification of the model. The authors proposed that future work would try to verify the theory with on slope experimental testing. The second paper applied the theory of machining to describe other skiing movements such as the hockey stop, traversing, and sideslipping down the fall line.

Finite element models and experimental methods were used by De Grau et al. to quantify the performance of an ice hockey helmet during impacts when struck by a striking implement with different compliancy (i.e. rigidity). Ice hockey has a high incidence of concussions and it is critical that hockey helmets protect the players during impacts. In the article, an ice hockey helmet was mounted on a Hybrid III headform and an unbiased neckform. Linear and rotational acceleration and rotational velocities were measured as inputs into finite element models. Based on the results, the helmet effectively reduced the magnitudes of key impact measures, but the effect was reduced as the striking cap

became more compliant. As such, the authors argue that designing ice hockey helmets to offer protection against impacts with objects of various compliance is an important consideration for future helmet designs.

Fontanella et al. demonstrated the usefulness of computational models to quantify the pressure and strain between a ski boot and the lower limb, which is linked to compromised ergonomics and comfort. A combination of experimental techniques was used to generate a three-dimensional computer aided design (CAD) model of the lower limb that included detailed models of the skeletal, biological, and soft tissue. The coupled ski boot and lower limb models were subjected to the ski boot buckling process to demonstrate the ability of the model to quantify properties such as interaction pressure, hydrostatic pressure, and compressive strain. The authors suggested that future work would use the model to simulation boot-limb pressure in dynamic skiing situations.

Based on this overview of the articles included in the collection, wearable sensors, instrumented equipment, and modelling were key approaches used across multiple areas of winter sports research. This highlights the potential for collaborations between these approaches and people in the field, (i.e. companies developing wearable sensors and engineers instrumenting the equipment) to help ensure that future winter sport technology and innovations have been rigorously tested and validated. Sports Engineering would welcome any further submissions that consider wearable sensor technology research to be submitted to the Topical Collection ‘Wearable Sensor Technology in Sports Monitoring’. There is also likely to be growth in the use of machine learning methods in future Sports Engineering research and our Editorial board includes key members to reflect this likely increase in submissions.

Thank you to all the authors for their contributions to this Winter Sports Topical Collection. Sports Engineering will continue to support research in the field of winter sports and we welcome any further submissions on the topic.

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