Abstract

Ski jumping, a prestigious Olympic discipline, has been constantly evolving. Over the years, the biomechanics fundamentals of this highly technical sport have been intensively documented by investigating the jump timing, kinematics, dynamics and motor control. This has increased our understanding of this discipline and resulted in the enhancement of the performance, in the development of new jumping techniques and in implications in safety and fairness. However, the performed analyses, based on standard measurement devices (e.g., 3D camera-based system, force plate), suffered from their complexity, time-consumption and related expenses. Consequently, they have been restricted to few athletes and focused on specific portions of the jump. On the other hand, to be compliant with the coaches’ and athletes’ needs, performance evaluation in daily routine relies primarily on feeling, visual observation and standard video analysis, but this type of evaluation suffers from subjectivity. Thus, nowadays, both scientists and field experts agree that there is a lack of an objective and simple assessment method for ski jumping.

In this thesis, we propose and assess a new wearable inertial-based system and dedicated methods usable in training practice to extract timing, angular, dynamic, and coordination parameters during the entire jump. Then, we use the system to characterize the entire ski jump and evaluate the key parameters relative to performance using a relatively large cohort of athletes.

The proposed measurement tool was devised to be easy-to-handle by coaches or athletes without the need for technical assistance. Within five minutes, the system was set up on the athlete and didn’t require any calibration constraints. The jumper was then ready for training as usual. After the training session, data were downloaded and then processed automatically in few seconds with the use of appropriate software.

The key temporal events and related ski jumping phases were automatically detected on the raw inertial signals using a pattern recognition technique. A new algorithm was designed to
monitor robust and drift-free orientations of skis and body segments for the entire jump sequence using a fusion of the inertial signals and specific biomechanical constraints during the jump. The dynamics of the take-off was evaluated using a forward kinematics model, while the flight aerodynamics was directly assessed using the inertial signals. The continuous relative phase was proposed to characterize the inter-segment coordination of lower-limbs during take-off. To assess the jump performance, traditional as well as new parameters describing the timing, the kinematics, dynamics and coordination were extracted. The proposed methods were assessed by their validity against reference measures when possible, by their consistency with the literature, and by their sensitivity to discriminate performance changes using athletes of different levels.

To characterize the entire ski jumping sequence, 33 athletes, ranging from junior to world-class, were monitored during training conditions (in total, 87 jumps recorded). The temporal, angular, coordination, and dynamic classes of parameters were extracted using the wearable inertial system for the take-off, early-flight, and stable flight, and they were compared to performance (the jump length) using different statistical approaches, i.e. bivariate correlation, multiple regression (partial least-square regression), and factor analysis. It showed that ski jumping is a complex sequence of movements involving numerous parameters.

This thesis proposed and assessed original inertial-based methods to evaluate the timing, kinematics, dynamics, and coordination in ski jumping. The measurement tool automatically extracts valid and sensitive parameters to characterize the performance and provides new insights by analysing the movement over the entire jump sequence. Giving a quantitative, rapid and personalized feedback with this new simple wearable system will help the athletes and coaches to better assess specific skills and improve the training efficiency.

**Keywords:** Ski jumping, Take-off, Early-flight, Stable flight, Training, Outcome evaluation, Performance, Entire jump, 3D Kinematics, Dynamics, Coordination, Timing, Biomechanics, Inertial sensors, Wearable measurement systems, Sensor fusion.