ANALYSIS AND RECONSTRUCTION OF HEAD KINEMATICS DURING ACCIDENTS IN FAST ALPINE SKIING DISCIPLINES

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The International Ski Federation has a body, the FIS Injury Surveillance and Prevention Program, to register and possibly prevent accidents. Almost every year, a report is drawn up in which all injuries suffered by athletes in all winter disciplines are categorised. In the latest published [1], drawn up in May 2019, it is clear that Alpine Skiing is one of the activities with the highest incidence of head injuries that can force athletes to an absence from competitions that sometimes exceed 28 days. Amongst the various characteristics that helmets for ski racing require is the shock absorption attitude, and this is tested in multiple ways depending on the certifications, both in terms of speeds and impact surfaces. Over the years, such standards have become more stringent, but the perception is that the optimal level of protection has yet to be achieved.
The purpose of this research was to analyse video footage of real-life accidents in World Cup Alpine Skiing to verify if there is a discrepancy between the helmets certification standards and the impacts actually suffered by the athletes.
Since it was decided to carry out this project partly using a video analysis software, Kinovea [2], to assess and track the movement of the head over time, it was of primary importance to evaluate its accuracy. We thus proceeded with a three-step validation of increasing difficulty and realism. In the first test, following [3], we measured the software's accuracy in measuring segments and angles from different viewpoints by comparing the results with a CAD software. Subsequently, videos of controlled falls of a human subject were analysed with Kinovea, comparing its results with a Motion Capture system. Finally, we recreated and examined footage possibly similar to an actual sports movie: a Hybrid III ATD was dropped vertically from known heights recording its flight and ground impact with a calibrated MoCap system and moving cameras placed around the scene. Accordingly, the aim was to compare the MoCap system's values with the study of the panning videos with Kinovea. What collectively emerged from these trials is that a sagittal view of the event under examination led to maximum accuracy, which gradually decreased moving from perpendicularity. This was valid for both static and non-static (panning) footage.
Once the accuracy of the video analysis software had been verified, a method for assessing the impacts was determined. The speed of the traced area was defined as a space/time relation, where the numerator was represented by the

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displacement measured by Kinovea and the denominator by the ratio between the number of frames analysed and the video FPS. The true impact velocity vector will be given by the vector sum between the apparent impact velocity of the skier within the frame and the movement speed of the camera, performed so that the subject remains as much as possible in the centre of the frame. After obtaining the true impact velocity, it must be decomposed into its generating components. In order to achieve this, since no geographic information regarding inclination in the impact zones and positioning of the cameras were known, it was necessary to consider the slopes as regular and infinite prisms and estimate their inclination using a GIS tool. These assumptions were used along with trigonometric rules to obtain the perpendicular to the slope component of the impact velocity. It has consequently been estimated that an incorrect assessment of these factors can cumulatively introduce an error that averages around 12%.

Comparing the results of our method with the impact speeds of helmets on flat anvils during the certification phase - 5.42 m/s for EN-1077A [4], 6.2 m/s for ASTM F2040 [5] and 6.8 m/s for FIS RH2103 [6] - it stands out that in almost 60% of cases, the testing standards were simultaneously exceeded. Of these, if we consider the cases that led to medically confirmed TBIs, we found that the average impact speed was almost 52% higher than the stricter regulation of 6.8 m/s.

Although it would be unrealistic to base new certification values solely on those found in this research, it is clear that there is an opportunity to improve further the protective capacity of ski racing helmets, which must be designed and tested under conditions representative of the environment in which they will be used and the typical accident scenarios.

In the future, in addition to focusing on the translational speeds of the impacts, it will be interesting to evaluate the accelerations to which the athletes are exposed in pre and post-impacts, as well as rotational speeds and accelerations.

The results of this work were presented with a critical and objective eye, avoiding any deception or exaggeration, as well as the representation of primary data findings in a biased way. Ethical approval was given by the University.

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