Study on Optimal Ski jumping takeoff Motions Using Data Analysis and CFD

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Summary

In this study, we focused on the take-off in ski jumping, an important factor that contributes to the jump distance, and clarified its characteristics by analyzing motion data and using fluid simulation. As a result of multiple regression analysis, Trunk_Angle and Hip_Angle were identified as the main factors that affect the jump distance. Furthermore, to verify the effect of differences in these angles on the jump distance from an aerodynamic point of view, we conducted an analysis of unsteady aerodynamic forces using CFD. As a result, we confirmed that these angles are closely related to the jump distance. The results of this study will contribute to the design of optimal take-off motions in ski jump and the improvement of competitive performance.

Introduction

Ski jumping is mainly composed of four movements: in-run, takeoff, flight, and landing. Among these movements, the take-off, which changes posture significantly in a short time of 0.2 to 0.3 seconds, is considered to be an important factor that contributes to the jump distance. However, it has not been possible to identify an appropriate take-off movement in terms of biomechanics and aerodynamics. Therefore, in this study, we aimed to classify various jumps using data analysis and to clarify the relationship between posture changes during take-off and the unsteady aerodynamic forces acting at that time using fluid simulation.

Methods

A total of 264 jumps by 40 athletes were recorded on video with 10 cameras, and the take-off movements were then analyzed using the markerless motion capture system(Theia3D). The obtained movement data was then used to perform multiple regression analysis and classify the take-off movements. Finally, 3DCG animations of representative movements from the classification were created, and computational fluid simulation (CFD) was used to analyze the unsteady aerodynamic forces during each take-off. After the animations were created, the CFD analysis was carried out using the framework developed by Yamamoto et al. [1]

Results and Discussion

Multiple regression analysis was performed on each of the 20 joints, and the results were as follows (Table1). Table 1 lists only the angles that show significance with a p-value of 0.05 or less. These results make it clear that the angles of Trunk_Angle and Hip_Angle (Figure1) are primarily important for increasing jump distance. However, it has not been fully elucidated why Trunk_Angle and Hip_Angle affect flight distance. Therefore, jumps with different Trunk_Angle and Hip_Angle sizes were selected, and the unsteady aerodynamic forces acting at each takeoff were analyzed using CFD. As a result, it was found that there were differences in the aerodynamic characteristics of each jump.

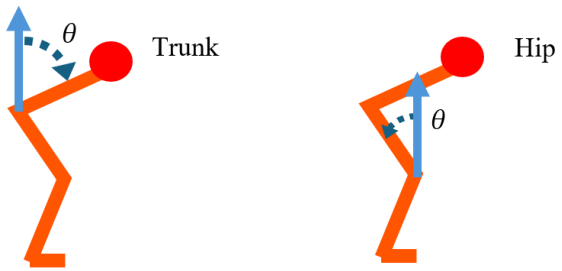

Figure 1: Definition of Trunk_Angle and Hip_Angle

Table 1: OLS Regression Coefficients

	Trunk	Hip	Pelvis	Head	Shoulder	Foot
Coef	-0.53	-0.35	0.25	0.19	-0.15	0.10

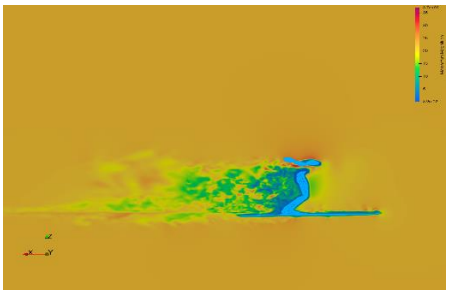

Figure 2: Velocity Visualization Diagram

Conclusions

This study shows that proper take-off motion in ski jumping is closely related to Trunk_Angle and Hip_Angle. It also revealed that there are differences in aerodynamic characteristics when the Trunk_Angle and Hip_Angle are different.

[1] Yamamoto, K, et al. "Numerical study of transient aerodynamic forces acting on a ski jumper considering dynamic posture change from takeoff to landing." Sports Biomechanics (2022): 1-15.