Analysis of Kinematic Factors in Take-off Motion Contributing to Ski Jumping Distance

Tomoya Ueno[1], Keizo Yamamoto[1]
[1]Graduate School of Hokusho University, Ebetsu, Japan
Email: tomo.quick1997@gmail.com

Summary

This study analyzed ski jumping take-off motions using markerless motion capture and principal component analysis (PCA), revealing four distinct movement types contributing to longer flight distances. The findings suggest that optimal take-off movement vary depending on an athlete's physique and skill level, indicating the importance of personalized training approaches over standardized techniques.

Introduction

In biomechanics research, the sequence of movements in ski jumping is divided into six phases: approach, take-off, early flight, stable flight, landing preparation, and landing. Among these phases, the take-off motion, characterized by significant postural changes occurring within a brief period of approximately 0.25 to 0.3 seconds, is considered to have a critical impact on flight distance [1]. However, there is currently no consensus among coaches and researchers on the optimal take-off posture. Furthermore, it is possible that individual athletes may require specific movements tailored to their physique and physical abilities. Therefore, the aim of this study was therefore to collect large-scale postural data using markerless motion capture and to analyze the kinematic factors contributing to ski jump distance by PCA.

Methods

The study included 31 ski jumpers (23 males, 8 females; age: 22.2 ± 7.2 years; height: 167.4 ± 7.5 cm; weight: 56.3 ± 5.4 kg; BMI: 20.1 ± 1.1 kg/m²). Participants ranged from junior high school students to adults, representing a wide age range and skill levels spanning junior, national, and international standards.

Measurements were conducted at the Miyanomori Ski jumping stadium in Sapporo, Japan (K = 90 m) using 10 synchronized video cameras. The landing points of the ski jumpers were also filmed in order to measure the flight distance. In this study, trials with flight distances of 90 m or longer (i.e. successful trials) were analyzed, totaling 73 trials.

The analysis employed markerless motion capture software (Theia3D, Theia markerless, Inc) to model body segments and estimate postures based on three-dimensional coordinates. The analysis focused on the anterior-posterior tilt angles of the trunk relative to the global coordinate system (trunk angle of attack), covering the time span from take-off (Take-off) to 0.2 seconds after take-off. Subsequently, PCA was performed using multivariate analysis software (Sift, HAS-motion, Inc), and the resulting principal component scores were used to examine the feature of take-off movement contributed with flight distance.

Results and Discussion

Principal component 1 was suggested to represent the magnitude of the trunk angle of attack waveform during the phase around 0.05 seconds after Take-off (variance explained: 85.1%). Principal component 2 was considered to capture the amount of change in trunk angle of attack within the analyzed range (variance explained: 12.0%).

The principal component scores for the trunk angle of attack in each trial were plotted in Figure 1. This figure shows that successful trials are distributed separately in four quadrants. This result suggests that there is diversity in successful trials.

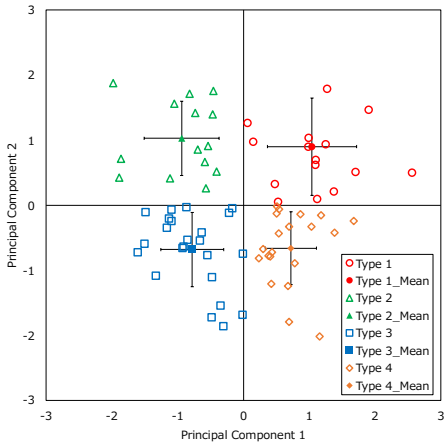

Figure 1: Scatter plots of principal component scores for trunk angle of attack.

Previous studies have identified that a smaller trunk angle of attack during take-off is a common characteristic among top-ranked athletes in senior competitions [2]. Based on the results of this study, it can be inferred that take-off movement required to achieve longer flight distances vary depending on an athlete's physique and skill level.

Conclusions

This study revealed four distinct take-off movement types for achieving longer flight distances, suggesting the importance of personalized approaches tailored to individual physique and skill levels over standardized movements.

References

[1] Schwameder H. (2008). Biomechanics research in ski jumping, 1991–2006. *Sports Biomechanics*, **57**: 114-136.

[2] Virmavirta M., Komi P.V. (1993b). Measurement of take- off forces in ski jumping: Part II. *Scandinavian Journal of Medicine & Science in Sports*, **3**: 237-243.