A KINEMATIC ANALYSIS OF THE FLIGHT PHASE OF SKI JUMPING

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INTRODUCTION

Ski jumping is a highly technical sport that requires precise timing and execution at high speeds in order for success. The movements must be performed accurately in each of the four phases of a jump, the in-run, take-off, flight and landing. Maximizing the flight is the general objective of all of the other phases of ski jumping. However, there are many independent factors of the flight phase which can have a large effect on the success of the jump. The take-off is generally considered the most crucial phase of a jump, however, this is assuming that the jumper has mastered the skill of flying. For the unskilled jumper, mastering flight technique can drastically improve results (Campbell, 1990). Research on describing an ideal flight position has focused on finding the position in which lift is greatest, while drag is minimized. However, this is somewhat impractical because, as lift increases, there is a proportional increase in drag . A high lift to drag ratio is indicative of the lift being greater than drag, therefore being an efficient flight position. A low lift:drag ratio indicates a larger drag force than lift, which results in much shorter jump distance (Campbell, 1990). A number of studies have provided groundwork information concerning ski jumping flight and have formed the basis upon which further studies should be conducted. Wind tunnel testing has played an important role in determining optimal flight positions and posture (Strauman, 1927; Tani and Iuchi, 1971; Ward-Smith and Clements, 1982). Remizov (1984) performed calculations using the data from Tani and Iuchi (1971), and found that the angle of attack should be small for the first part of flight in order to reduce drag. The angle of attack should then be increased during the second part of flight to achieve maximum lift. Pulli (1989) described optimal flight as having the greatest lift and angle of attack during the first part of flight, with a more efficient aerodynamic position during the second part of flight. While it has been recognized that flight parameters affect the success of the flight, little research has been done to measure these parameters in the real competitive environment. The purpose of this study was to identify and quantify selected kinematic variables associated with the flight phase of ski jumping and to determine the relationship between each variable and the distance jumped.

EXPERIMENTAL PROCEDURES

The subjects for the investigation were 46 highly skilled competitors participating in the first round of the 1995 Springertournee K-110 World Cup event. Data were collected using a Panasonic SVHS video camera equipped with a high speed shutter. The data was sampled at a rate of 60 FPS. The camera was levelled and positioned at a 90 degree angle to the plane of motion. The camera was located 36.9 meters from the path of motion, which allowed a field width of 25 meters. Located in the field were 3 marks, placed 8 meters apart at critical points in the flight phase. Data for the distance jumped were collected from the competition records. The 2D Peak Performance Video Analysis System was used to extract the horizontal and vertical coordinates for a 5 point segmental model. The C/M was then calculated through use of a model consisting of trunk and legs. The data was smoothed using a second order Butterworth digital filter and processed to compute linear and angular displacements and velocities. Further measurement and calculations were performed to calculate the angles of ski and leg, trunk and ski, ski and direction, leg and direction, trunk and direction, the angle of the flight curve and the distance of the C/M to the landing(Refer to Figures 1&2). Descriptive and correlational analysis of selected variables was performed using SPSS.

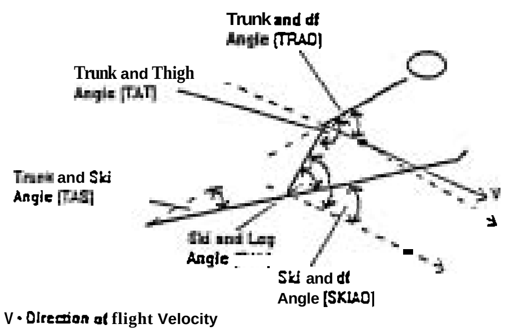

Figure 1. Skier-ski System and Direction of Flight Variables.

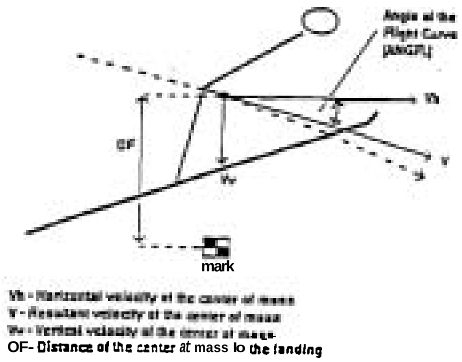

Figure 2. Velocity and Flight Direction Variables.

RESULTS & DISCUSSION

Trunk and Thigh Angle (TAT): The best jumpers were able to have a large TAT angle, possibly due to the ability of the jumpers to flatten out during the second part of the flight phase with the skis spread wide apart at the tips in the V-Style flight.

Ski and Leg Angle (SAL): The results suggest SAL angle is strongly associated with distance jumped. SAL angles are smaller for the V-Style flight than observed in previous studies.

Trunk and Ski Angle (TAS): The best jumpers showed a very small TAS angle that decreased through the analyzed phase. This small angle results in the jumpers trunk being nearly parallel with the skis, which probably increases the

aerodynamic efficiency.
Ski and Direction of Flight Angle (SKIAD): The results showed the best jumpers to have an average angle of 40 degrees for SKIAD.
Leg and Direction of Flight Angle (LEGAD): The best jumpers showed a small LEGAD angle, referred to as a more "forward" position, which is associated with a more aerodynamic position and greater distance jumped.
Trunk and Direction of Flight Angle (TRAD): The angles of TRAD remained fairly constant for the best jumpers through the analyzed phase, at slightly greater than 40 degrees.
Horizontal Velocity (Vh): The best jumpers achieved an increase in horizontal velocity, possibly due to a gliding effect.
Distance of the Centre of Mass to the Landing (DF): The results suggest that the best jumpers were able to slow their descent to the landing hill somewhat, probably due to good flight characteristics (Refer to Figures 3&4)..
Angle of the Flight Curve (ANGFL): The mean ANGFL angles increased for all of the jumpers through the analyzed phase, but to a lesser degree for the most skilled jumpers.

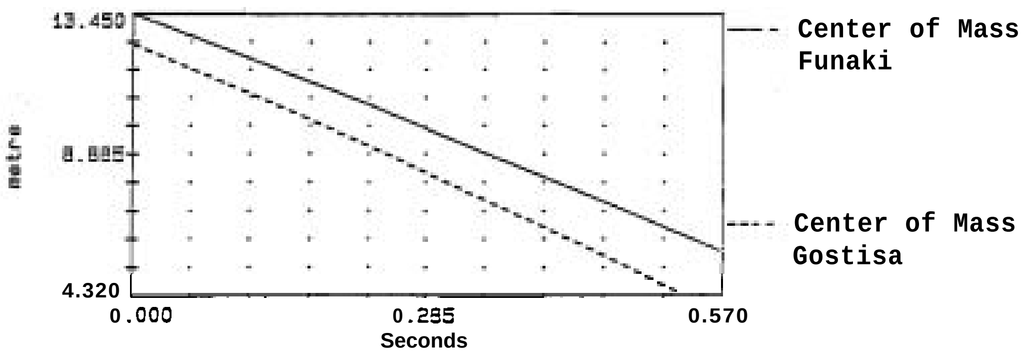

Figure 3. Vertical Displacement of C/M Over Time for the Best vs. Worst Jump.

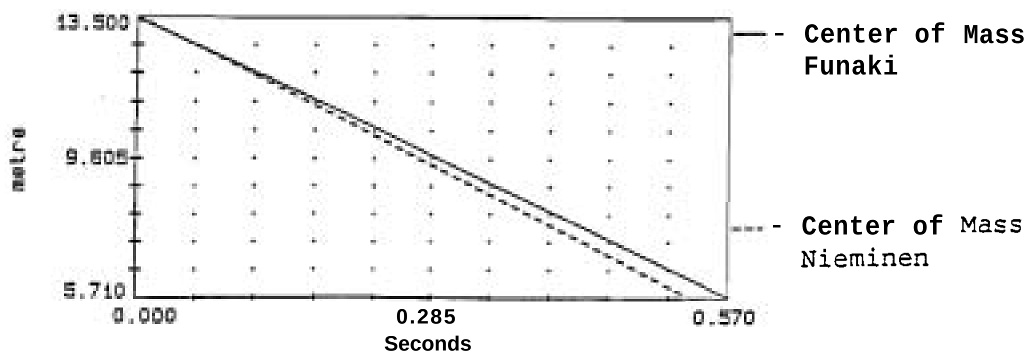

Figure 4. Vertical Displacement of C/M Over Time for the Best vs. Next Best Jump.

CONCLUSIONS

1. The results of the analysis suggest that jumpers who want to increase their distance jumped should increase their ski and leg angle, decrease the trunk and ski angle throughout the flight phase, maintain an angle of approximately 40 degrees for the angle of the ski and direction and the angle of the trunk and direction during the second part of the flight phase, and hold a flight position with a small leg and direction of flight angle.
2. The technique of jumpers using the V-style for the analyzed flight phase differed slightly for the trunk and ski angles and the ski and leg angles from what has been described in the literature for the traditional jump style.
3. The results support the recommendations in the literature of a position of greatest lift during flight entry, and a position of greatest aerodynamic efficiency for the second part of the flight phase.
4. Further study of the increase in horizontal velocity during flight for the best jumpers is necessary in order to determine how to optimize this effect.

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