# THREE TECHNIQUES OF SKI JUMP TAKE-OFF MODELED BY CHANGES OF JOINT ANGLE

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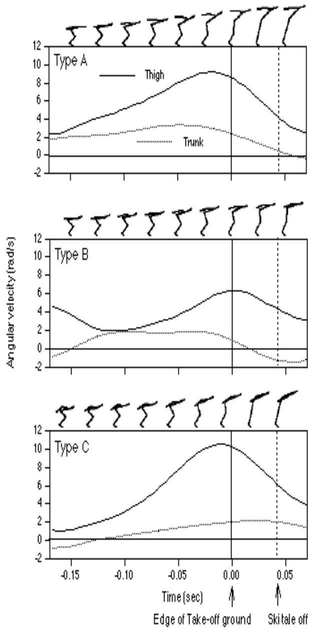
**INTRODUCTION:** Ski jumping can be divided into five phases: the start, approach run, take-off, flight, and landing. The take-off is the most critical phase affecting the jumper's flight distance (Virmavirta & Komi, 1993b). Take-off action moves the jumper's center of mass upward. Ascent force gives the jumper altitude for the flight phase (Sasaki et al., 1989). An optimum flight posture decreases the drag force that a jumper is subjected to in the initial flight phase. Flight posture is also affected as a consequence of take-off action. The two major take-off objectives, ascent force and optimum flight posture, must be achieved by jumpers during high speed ski gliding. Jumpers should aim for optimum movement of the joints, because reaction force is the result of the integrated kinetic parameters of each joint or segment (Sasaki et al., 1997). However, kinetic parameters are difficult for coaches to explain, and the collecting of data from video is time consuming. Direct force plate measurements can show useful data to coaches and jumpers immediately after performance. Force information is therefore useful in training for both coaches and jumpers (Komi & Virmavirta, 1997). In our opinion, however, biomechanical data must be explained in non-technical terms. It is important when coaching that biomechanical information be simple, specific, visual, precise, and prompt.
It would be better for coaches to represent the desired take-off actions by joint angle rather than joint power. The purpose of this study is to establish visual models of ski jump take-off action for world class jumpers based on changes of joint angle in order to create a useful coaching system.
**METHOD:** The take-off action of four jumpers was analyzed from video taken at the Intercontinental Cup Summer Competition at the Hakuba normal jump hill in 1997. Camera (made by NAC Co.) speed was 240 frames per second. We observed kinematics and kinetic parameters from actual ski jumps, using seven segment linkage models of five degrees of freedom. The moment of inertia was obtained using Winter's method (Winter, 1990).
**RESULTS:** Most of the angular velocity, from initial action until take-off, is produced by two joints, the hip and the knee joint. The maximum angular velocity in the knee joint takes place close to the edge of the take-off platform in all jumpers. Figure 1 demonstrates the relative changes in the joints for all jumpers. It also indicates the trend of extension for knee and hip joints. The direction of extension in each segment is indicated by a positive value of angular velocity. The thigh segment's angular velocities are depicted by a solid line. In the thigh segment, the maximum values appeared close to the take-off edge. In Type-A, the maximum angular velocity in the thigh segment was observed -0.021 sec. before take-off. Most of the power, from initial action until take-off, was produced by two joints, the hip and the knee joint. All jumpers had no forward rotation, as seen in the stick diagram in Figure 2. Joint power was produced in regular order for Type-A and



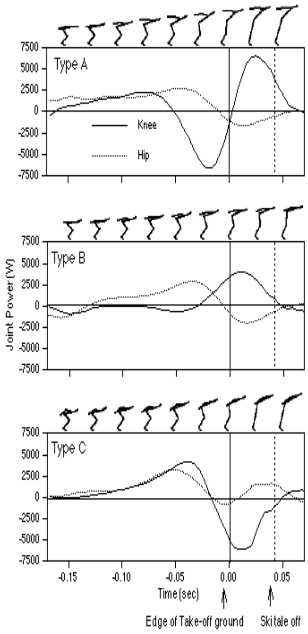




Figure 1. Trunk and thigh angular velocity Figure 2. Hip and knee joint power contrasted with stick diagrams in all techniques contrasted with stick diagrams in all technique.

Type-B. The knee joints play an important role in generating the power in each jump technique.

For each type the manner of power generation can be seen more clearly in the kinetic than in the kinematics analysis. In a comparison of the values of hip and knee power, greater power is recognized in the hip than in the knee joint. Changes in hip and knee joint power had positive values until maximum power production. The interval from initial power occurrence to maximum value was different in each joint. In Type-A, the maximum value of knee joint power was observed -0.087 sec. before take-off. The values exceeded 2254.7 watts. The maximum power of the hip exceeded 2706.3 watts, and the interval from peak to take-off was 0.046 sec. Power production in each joint took place in a regular orderly manner from hip to knee. The hip joints were the major power producers in Type-A. Hip joint power had the first peak at the initial action phase, after some delay the first peak appeared in the knee joints, and after some delay hip joint power achieved the maximum value before take-off.

The manner of joint power appearance in Type-B also showed a tendency similar to that in Type-A, but knee joint power showed positive values in the initial action phase. The knee joint in Type-B had greater power than the hip joint in the initial action phase. The maximum value of knee joint power was observed 0.008 sec after take-off. The values exceeded 3955.8 watts. Power production in each joint took place in a regular orderly manner from knee to hip.

The technique in Type-C is characterized by the close power generation of the two joints. This performance shows an example in which the maximum knee and hip joint power were produced at approximately the same time. For that reason, the total power was very large. The maximum power of the hip exceeded 3250 watts, the knee exceeded 4178.7 watts, and the total exceeded 8600 watts. The intervals from peak power production to take-off for both hip and knee were almost the same. Hip and knee joints produced power in a similar manner.

**DISCUSSION:** Jump performances were classified into three techniques according to the production of angular velocity. The first technique, Type-A, showed the tendency that the trunk segment and after some delay the thigh segment produced maximum angular velocity on the take-off platform. Type-B indicates the tendency that the thigh segment and after some delay the trunk segment produced maximum angular velocity on the take-off platform. Particularly the maximum angular velocity of the trunk segment appeared just after take off from the edge of the platform. In Type-C, both trunk and thigh angular velocity increased in parallel until maximum. In this technique both hip and knee joints were extended at almost the same time. Three types of jump action could be represented simply by visual models. Three motion models are shown in Figure 3. Three techniques in the manner of jump action could be classified according to the production of angle and angular velocity in the hip and knee joints. There was no backward motion at the ankle joint observed in any of the three techniques.

Joint power is a mechanical concept which is calculated by the outer product of torque and angular velocity in that joint. Power production in each joint took place in regular order in the two techniques, Type-A and Type-B, indicated by Figure 2. In Type-A, the ascent power in the knee joint was produced later than in the hip joint. This orderly manner indicates energy transmission from upper body to lower body (Winter, 1990). This orderly manner of joint power production supports our previous study (Sasaki, et al., 1993). Type-A indicates a motion in which the upper body rose initially. The motion of the upper body would create a larger ascent momentum but would also result in a larger body area to be subjected to aerodynamic drag force. Therefore, a jump in Type-A would be able to obtain the highest position after the take-off but would also be subjected to a large aerodynamic force (Tani & Iuchi, 1971), (Luethi & Denoth, 1987). Type-B indicates a motion in which the thigh segment rose initially. This initial action is the characteristic movement of Type-B. The motion of the thigh segment would create a forward momentum and make a narrower body area to be subjected to aerodynamic drag force. Therefore, this technique, Type-B, will have the advantage of a decrease in aerodynamic drag force (Jin et al., 1995), but also a risk of decreasing jump height. In Type-C, the maximum powers were produced at approximately the same time, but the values of knee joint power were larger than for the hip joint. Also, thigh angular velocity was larger than in the trunk. In Type-C, the motion of the upper body would not only be able to create greater joint power, but also to make a narrower body area subjected to aerodynamic drag force. Using this technique, jumpers can obtain enough ascent force to increase jump height. Therefore, it can be recognized that this technique has advantages in both power generation and in making a narrow body area (Jin et al., 1995). However, there might be difficulty in timing the beginning ascent motion.

**CONCLUSION:** This study clarifies the ski jumping techniques of four expert jumpers based on an analysis of patterns of angular velocity and joint power. Useful visual models for visual explanation were established from kinematics and kinetic parameters. Our conclusions are as follows: (1**)** The maximum angular velocity in the knee joint takes place at close to the edge of the take-off platform for all jumpers. (2) Angular velocity in the thigh was larger than in the trunk segment. (3) The action at the hip joint represented the characteristics of jump technique rather than the action at the knee joint. (4) Three types of jump action could be represented simply by joint angle as visual models. (5) There are advantages and risks involving jump height and the amount of body area subjected to the aerodynamic drag force associated with each technique.

**REFERENCES:**

Jin, H., Shimizu, S., Watanuki, T., Kubota, H., Kobayashi, K. (1995). Desirable Gliding Styles and Techniques in Ski Jumping. *J. of Appl. Biomech.* **11**, 460-474 .

Komi, P. V., Virmavirta, M. (1997). Ski-Jumping Take-Off Performance: Determining Factors and Methodological Advances. In E. Müller, H. Schwameder, E. Kornexl, C. Raschner (Eds.), *Science and Skiing* (pp. 3-26 ). London: E & FN Spon .

Luethi, S. M., Denoth, J. (1987). The Influence of Aerodynamic and Anthoropometric Factors on Speed in Skiing. *International Journal of Sport Biomechanics* **3**, 345-352 .

Sasaki, T., Tsunoda, K., Nishizono, H. (1989). Video Analysis of Take-Off Actions in Ski Jumping. In R. J. G. et al. (Ed.), *XII Int. Cong. of Biomech, Congress Proceedings* (pp. 203-204). Los Angeles: UCLA.

Sasaki, T., Tsunoda, K., Uchida, E. (1993). The Effect of Segment Power in Ski Jumping. In *14th Int. Cong. Biomechanics* (pp. 1186-1187). Paris.

Sasaki, T., Tsunoda, K., Uchida, E., Hoshino, H. (1997a). Classification of Ski Jump Take-Off Techniques by Joint Power. In M. Miyashita, M. Fukunaga (Ed.), *16th Int. Cong. Biomechanics* (pp. 258). Tokyo: The University of Tokyo.

Tani, I., Iuchi, M. (Ed.). (1971). Flight-Mechanical Investigation of Ski Jumping. Tokyo: Hitachi, Ltd.

Virmavirta, M., Komi, P. V. (1993a). Measurement of Take-Off Forces in Ski Jumping Part I. *Scandinavian J. of Medicine and Science in Sports* **3**, 229-236 .

Virmavirta, M., Komi, P. V. (1993b). Takeoff Analysis of a Champion Ski Jumper. In *14th Int. Cong. Biomechanics. Proceedings* (pp. 1418-1419).

Winter, D. A. (1990). Biomechanics and Motor Control of Human Movement. London: Wiley Inter-Science Publications.

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