BIOMECHANICAL CHARACTERISTICS OF TAKEOFF PREPARATION AND TAKEOFF MOTION IN DIFFERENT JUMPING TYPES OF ELITE MALE LONG JUMPERS

Yutaka Shimizu[1], Michiyoshi Ae[2] and Hiroyuki Koyama[3]

Graduate School in Health and Sports Sciences, University of Tsukuba, Japan[1]
Faculty of Health and Sports Sciences, University of Tsukuba, Japan[2]
Faculty of Education, Kyoto University of Education, Japan[3]

This study investigated the biomechanical characteristics of takeoff preparation and takeoff motion for different types of elite male long jumpers. The subjects were 19 elite male long jumpers whose motion from the second to the last stride to takeoff was videotaped. The subjects were classified into two horizontal type (H-type) and vertical type (V-type) jumpers, based on the mean takeoff angle. The results are summarized as follows. (1) H-type jumpers tended to keep the trunk leaning forward and to retain their horizontal center of gravity (CG) velocity during takeoff preparation and takeoff phases. (2) V-type jumpers tended to extend the knee joint of the takeoff leg significantly at the touchdown of the takeoff phase and to obtain large vertical CG velocity by forward rotation of the body during the first half of the takeoff phase.

KEY WORDS: long jump, motion analysis, kinematics.

INTRODUCTION: A number of biomechanical studies on takeoff motions of the long jump have focused on the relationship between center of gravity (CG) velocity and jumping distance. In particular, these studies have investigated the takeoff techniques to obtain high vertical CG velocity while retaining as much horizontal CG velocity as possible. Some of these studies have addressed several jumping types. Koh and Hay (1990) classified jumping types based on body position at the touchdown of the takeoff phase. Saito and Ae (1991) classified student long jumpers based on change in CG velocity during the takeoff phase. However, Okano (1989) warned that many Japanese long jump coaches tended to emphasize higher jumping for most long jumpers, regardless of the jumper's characteristics, perhaps because they had no clear index to classify long jumpers, and no appropriate model of jumping types to use in the coaching and training of long jumpers. Therefore, this study investigated biomechanical characteristics of takeoff preparation and takeoff motion for different types of elite male long jumpers.

METHODS: The subjects of this study were 19 elite male long jumpers (height, 1.80 ±0.07 m; body mass, 71.26 ±6.32 kg; record, 8.12 ±0.31 m). Their motion from the second to the last stride to takeoff in international competitions was videotaped by high-speed VTR cameras NAC HSV-500C^3 (250Hz) and CASIO EXILIM EX-F1 (300 Hz). The trial in which each subject had the best jumping distance at the competition was selected to be digitized with a Frame DiasII system (DKH Co., Japan). Three-dimensional coordinates of 23 landmarks of the body for a 14-segment model were reconstructed using the DLT technique. The coordinate data were smoothed with a Butterworth low-pass digital filter with optimal cut-off frequencies (5 to 10Hz), determined by the residual error method.
Figure 1 plots the relationship between horizontal and vertical CG velocity at the instant of toe-off of the takeoff phase for all the subjects. The subjects were classified into horizontal type (H-type) or vertical type (V-type) jumpers, based on the mean takeoff angle of the all subjects (22.03 ±1.98°). Eight subjects with lower takeoff angle than the average were classified as H-type, and 11 subjects with takeoff angles higher than the average were classified as V-type.
The standard motions of H-type and V-type jumpers were established using the method of Ae et al. (2007); the coordinate data normalized by the motion phase time and the subject's height were averaged.

Takeoff preparation and takeoff motion were divided into five phases: from the touchdown (on) to the toe-off (off) of the second to the last (L2) stride (L2-support phase), from L2-off to L1-on (L2-flight phase), from L1-on to L1-off (L1-support phase), from L1-off to TO-on (L1-flight phase), and from TO-on to TO-off (TO-support phase). Each phase was set as 100% time. The TO-support phase was further divided into two phases: from TO-on to the instant of maximum knee flexion (MKF) of the takeoff leg as the first half of the takeoff phase, and from MKF to TO-off as the second half. The calculated kinematic parameters were CG velocity, takeoff angle, and joint and segment angles. The unpaired t-test was used to test differences between H-type and V-type, with a significance level at 5%.

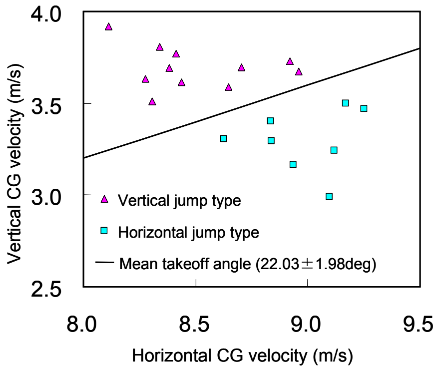

Figure 1: Horizontal CG velocity and vertical CG velocity at the instant of toe-off of the takeoff phase.

RESULTS: Table 1 indicates the jumping distance and parameters of CG velocity at the instants of TO-on, MKF, and TO-off of the takeoff phase for H-type, V-type, and all subjects. The jump distance was the same for both types of jumpers. The takeoff angle for V-type was significantly greater than for H-type. The horizontal CG velocities at the instants of MKF and TO-off for H-type were significantly greater than for V-type. Vertical CG velocity of the instants of MKF and TO-off for V-type was significantly greater than for H-type. The decrease in horizontal CG velocity during the first half of the takeoff phase was significantly smaller for H-type than for V-type. The increase in vertical CG velocity during the first half of the takeoff phase was significantly greater in V-type than in H-type.

Figure 2 presents a series of stick pictures of the standard motion for H-type and V-type during takeoff preparation and takeoff phases. Selected characteristics observed from the standard motions are as follows.

(1) H-type jumpers kept the trunk leaning forward during the takeoff preparation phase (1, 2, and 3 in Figure 2). The backward lean of the trunk at the instant of TO-on was smaller in H-type jumpers than in V-type jumpers (5 in Figure 2).

(2) V-type jumpers exhibited greater flexion of the knee joint of the support leg during the L1 support phase (2 in Figure 2) and greater extension of the knee joint of the takeoff leg at the instant of TO-on (5 in Figure 2) than H-type jumpers did.

(3) The forward lean of the trunk and the shank of the support leg at the instant of TO-off (7 in Figure 2) were greater in H-type jumpers than in V-type jumpers.

Table 1: Jumping distance and parameters of CG velocity at the instants of TO-on, MKF, and TO-off of the takeoff phase for H-type, V-type, and all subjects.

	H-type	V-type	All subjects	Difference
Jumping distance (m)	7.99 (0.26)	7.95 (0.34)	7.97 (0.30)	n.s.
Angle_TO-on (deg)	-1.46 (1.13)	-1.73 (1.60)	-1.62 (1.39)	n.s.
Angle_TO-off (deg)	20.07 (1.01)	23.45 (1.02)	22.03 (1.98)	p<0.01
HV_TO-on (m/s)	10.32 (0.27)	10.07 (0.24)	10.18 (0.27)	n.s.
HV_MKF (m/s)	9.36 (0.22)	8.86 (0.27)	9.07 (0.35)	p<0.01
HV_TO-off (m/s)	8.99 (0.21)	8.50 (0.27)	8.71 (0.35)	p<0.01
VV_TO-on (m/s)	-0.26 (0.20)	-0.31 (0.28)	-0.29 (0.25)	n.s.
VV_MKF (m/s)	2.05 (0.38)	2.44 (0.25)	2.28 (0.36)	p<0.05
VV_TO-off (m/s)	3.28 (0.17)	3.69 (0.11)	3.52 (0.24)	p<0.01
Decrease_HV_{first} (m/s)	-0.95 (0.19)	-1.22 (0.19)	-1.11 (0.22)	p<0.05
Decrease_HV_{second} (m/s)	-0.37 (0.14)	-0.36 (0.18)	-0.36 (0.16)	n.s.
Decrease_HV_{total} (m/s)	-1.32 (0.20)	-1.57 (0.18)	-1.47 (0.22)	p<0.05
Increase_VV_{first} (m/s)	2.32 (0.48)	2.74 (0.39)	2.56 (0.47)	p<0.05
Increase_VV_{second} (m/s)	1.23 (0.31)	1.25 (0.23)	1.24 (0.26)	n.s.
Increase_VV_{total} (m/s)	3.55 (0.33)	3.99 (0.26)	3.80 (0.36)	p<0.01

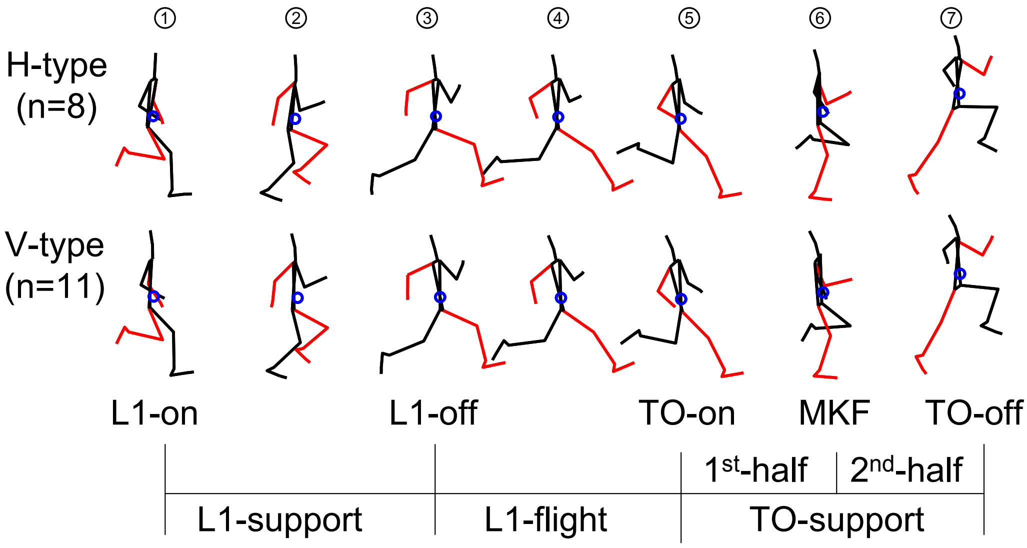

Figure 2: Stick pictures of the standard motion for H-type and V-type of elite male long jumpers during takeoff preparation and takeoff phases.

Figure 3 plots change in CG height (% body height) from L1-on to TO-off for H-type and V-type jumpers. The CG height around L1-off to MKF was significantly greater in H-type jumpers than in V-type jumpers. However, no significant difference in CG height during the second half of the takeoff phase was observed between types of jumpers.

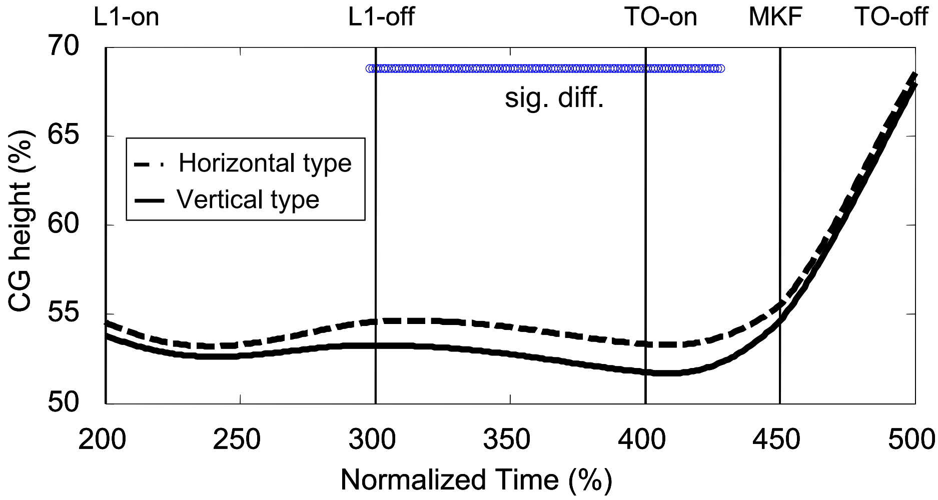

Figure 3: Change in CG height from L1-on to TO-off for H-type and V-type jumpers.

DISCUSSION: Takeoff preparation and takeoff in the long jump seek to obtain vertical CG velocity while retaining as much horizontal CG velocity as possible (Hay, 1993). In the present study, although significant differences in horizontal and vertical CG velocities were observed at the instant of TO-off, no significant difference in jumping distance was observed. The increase in vertical CG velocity during the first half of the takeoff phase was greater in V-type jumpers than in H-type. These results clearly indicate that conversion of horizontal CG velocity into vertical velocity in the first half of the takeoff phase is a major factor in classifying elite male long jumpers.

H-type jumpers tended to keep the trunk leaning forward during takeoff preparation and takeoff phases. Morinaga et al. (2003) compared the takeoff preparatory and takeoff motion between good and poor jumps for six male long jumpers. They found that with good jumps the trunk leaned forward at the takeoff, and the horizontal CG velocity decreased less than with poor jumps. The present results and Morinaga's finding indicated that H-type jumpers were able to retain greater horizontal CG velocity because of the forward lean of the trunk during the takeoff preparation and takeoff phase, implying the importance of the trunk lean. V-type jumpers tended to flex the knee joint of the support leg more deeply during the L1-support phase to keep the CG height lower from the L1-off to the MKF. Lees et al. (1993) noted that lowering the CG in the preparatory phase was necessary for long jumpers to project the CG in an optimum angle. However, the present results indicate that deep flexion of the support knee joint in the preparation phase may result in greater loss of horizontal CG velocity. V-type jumpers tended to lean the trunk backward earlier and to extend the knee joint of the takeoff leg significantly at the instant of TO-on. These motions may be effective in obtaining vertical CG velocity, due to the forward rotation of the body about the takeoff foot during the first half of the takeoff phase, at the expense of loss of horizontal CG velocity. Sports techniques always need compromise.

CONCLUSIONS: Elite male long jumpers could be classified into two types, H-type and V-type, based on the takeoff angle. H-type jumpers tended to keep the trunk leaning forward and to retain horizontal CG velocity during takeoff preparation and takeoff phases. V-type jumpers tended to extend the knee joint of the takeoff leg significantly at TO-on and to obtain vertical CG velocity largely due to the forward rotation of the body about the takeoff foot during the first half of the takeoff phase.

REFERENCES:

Ae, M. ,Omura, I., Kintaka, H., Iiboshi, A., Yamada, A., Ito, N.,& Ueda, T. (1999). A biomechanical analysis of the takeoff preparation motion by elite long jumpers (in Japanese), *Research Quarterly for Athletics*, 63, 28-35.

Ae, M., Muraki, Y., Koyama, H., & Fujii, N. (2007). A biomechanical method to establish a standard motion and identify critical motion by motion variability: With examples of high jump and sprint running. *Bulletin of Institute of Health and Sport Sciences University of Tsukuba*, 30, 5-12.

Hay, J.G.(1993). Citius, Altius, Longius (Faster, Higher, Longer): The biomechanics of jumping for distance. *Journal of Biomechanics*, 26, 7-21.

Koh, T. J. & Hay J. G. (1990). Landing Leg Motion and Performance in the Horizontal Jumps I: The Long Jump, *International Journal of Sport Biomechanics*, 6, 343-360.

Lees, A., Fowler, A. & D. Derby(1993). A biomechanical analysis of the last stride, touch-down and take-off characteristics of the woman's long jump. *Journal of Sports Sciences*, 11, 303-314.

Morinaga, M., Yasui, T., Jyujyo, A., Kato, H., Okano, Y., Koyama,Y.,& Sawamura, H. (2003). The differences of the motions between good jumps and poor jumps from each preparatory motion for takeoff through takeoff in long jump (in Japanese), *Research Quarterly for Athletics*, 52, 12-21.

Okano, S. (1989). Long jump and Triple jump (in Japanese), New Track and Field series 7, *Baseball Magazine Co.*, 22-25 .

Saito, N. & Ae, M. (1991). A study of the method of classification of the takeoff motion in long jump (in Japanese), *Research Quarterly for Athletics*, 52, 12-21.