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A BIOMECHANICAL STUDY OF THE TAKEOFF PREPARATION AND THE TAKEOFF MOTIONS IN ELITE MALE LONG JUMPERS

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The purpose of this study was to compare the takeoff preparation and the takeoff motions of the world level and Japanese long jumpers by using the method of the standard motion. The subjects were nine World jumpers (World group) and ten Japanese jumpers (Japan group). The motion from the second-last stride to the takeoff was videotaped by two high-speed VTR cameras. The standard motions of World and Japan group were established by using the method of Ae et al. (2007). The results were summarized as follows; 1) The World group indicated the greater horizontal CG velocity and smaller decrease in the horizontal CG velocity during the takeoff preparation and takeoff than those of the Japan group. 2) The Japan group tended to flex and extend the knee joint of the support leg, and to raise the trunk in earlier timing during the preparation phase.

KEY WORDS: long jump, standard motion, motion analysis.

INTRODUCTION: A long jump consists of five phases—the approach, takeoff preparation, takeoff, flight, and landing. The most important factor in the takeoff preparation and the takeoff phases of the long jump is to maintain as much horizontal velocity obtained in the approach as possible and transform it into great vertical velocity with a minimum loss (Ae, 1999).
Ae et al. (2007) proposed a biomechanical method to provide a standard motion as an averaged motion pattern of skilled performers for learning sports techniques. This method enables us to investigate the characteristics of the takeoff preparation and the takeoff motions for the world level and the Japanese elite male long jumpers. The purpose of this study was to compare the takeoff preparation and the takeoff motions of the world level and Japanese elite male long jumpers by using the method of the standard motion and to obtain suggestion for the improvement in the jump performance of Japanese long jumpers.

METHODS: The subjects of this study were nine finalists (height, 1.85±0.07m; weight, 74.22±6.83kg; record, 8.21±0.21m) in the men's long jump at the 2007 IAAF World Championships in Athletics, Osaka (World group) and ten Japanese long jumpers (height, 1.76±0.04m; weight, 68.60±4.67kg; record, 7.75±0.17m) who participated in the final of 2008 JAAF Japan Championships in Athletics (Japan group). The motion from the second-last stride to the takeoff was videotaped by two high-speed VTR cameras, NAC HSV-500C[3] (250Hz) for the World group and CASIO EXILIM EX-F1 (300Hz) for the Japan group, respectively. The trial in which each subject showed the best jumping distance was selected to be digitized with Frame Dias Ⅱ system (DKH Co., Japan).
Three dimensional coordinates of twenty-three landmarkers defining a fourteen-segment model were reconstracted by using a three DLT technique. The coordinates data were smoothed with a Butterworth low-pass digital filter with optimal cut-off frequencies, determined by the residual error method proposed by Wells and Winter (1980). The standard motions of World and Japan groups were established by using the method of Ae et al. (2007). The coordinates data were normalized by the motion phase time and the subject's height, and the normalized data were averaged. The takeoff preparation and takeoff motions were divided into five phases: from touchdown (on) to toeoff (off) of the second 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). Then, each phase was normalized as 100% by each phase time.

The calculated kinematic parameters were the velocity of the center of gravity (CG), the takeoff and landing angles, and the joint and segment angles. The Mann-Whitney U-test was used with a significance level set at 5% to test differences between the World and the Japan groups.

RESULTS: Table 1 shows the CG velocities at the instants of touchdown (on) and toeoff (off) of the takeoff preparation and the takeoff phase for the World and the Japan groups. The horizontal CG velocities of the instants from L2-on to To-off for the World group were significantly greater than those of the Japan group. The decrease in the horizontal CG velocitiy during support phases for the World group were slightly smaller than those of the Japan group. The vertical velocity at L2-off for the World group was significantly smaller than that of the Japan group. Only the takeoff angle (the angle between the CG velocity vector at the toeoff and the horizontal line) at L2-off was significantly smaller in the World group than that of the Japan group.

Table 1
The parameters of the CG velocites at the instants of touchdown (on) and toeoff (off) of the takeoff preparation and the takeoff phase for the World and the Japan groups.

		L2		L1		To	
		on	off	on	off	on	off
Horizontal velocity (m/s)	World	10.61±0.28	10.59±0.37	10.61±0.19	10.47±0.27	10.30±0.29	8.85±0.33
	Japan	10.37±0.26	10.27±0.27	10.31±0.25	10.13±0.22	10.05±0.22	8.57±0.32
	U-test	*	*	**	**	*	*
Vertical velocity (m/s)	World	-0.45±0.14	0.08±0.25	-0.92±0.15	0.07±0.22	-0.10±0.21	3.45±0.29
	Japan	-0.52±0.14	0.34±0.13	-0.91±0.14	0.04±0.20	-0.41±0.14	3.59±0.18
	U-test	n.s.	**	n.s.	n.s.	**	n.s.
Landing angles (deg)	World	-2.4±0.8		-5.0±0.8		-0.6±1.2	
	Japan	-2.9±0.8		-5.1±0.8		-2.3±0.8	
	U-test	n.s.		n.s.		**	
Takeoff angles (deg)	World		0.5±1.4		0.4±1.2		21.3±2.1
	Japan		1.9±0.7		0.3±1.1		22.8±1.6
	U-test		**		n.s.		n.s.

(* p < .05; ** p < .01)

Fig. 1 illustrates stick pictures of the standard motions for the World and Japan groups during the takeoff preparation and the takeoff in the long jump. Some characteristics observed from the standard motions would be as follows:
1) The flexion and extension of the knee joint of the support (left) leg during the L2 support phase for the World group was smaller than that of the Japan group (1-3 in Fig. 1).
2) The World group kept the trunk leaned forward during the takeoff preparation phase, and the backward lean of the trunk around the To-on for the World group was smaller than that of the Japan group (8-10 in Fig. 1). The trunk for the World group was leaned forward at the To-off, while the Japan group leaned their trunk backward slightly.

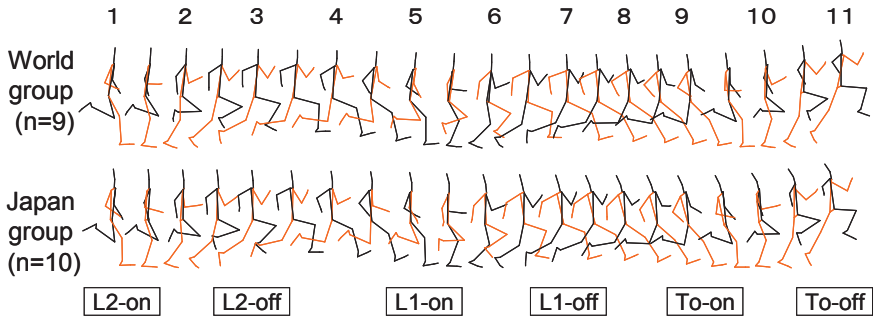

Figure 1: The standard motions for the World and the Japan made long jumpers during the takeoff preparation and takeoff.

DISCUSSION: The aim of the takeoff in the long jump is to obtain vertical CG velocity while retaining as much horizontal CG velocity as possible (Hay, 1993). In the present study, there was the difference in the horizontal CG velocity. The World group showed smaller loss in horizontal CG velocity during the takeoff preparation and the takeoff phases as Hay described.
Most athletes in the Japan group showed a so-called 'step-up' motion at the L2-off. This motion might be caused by paying too much attention to the long part of 'long-short 'rhythm in the takeoff preparation. The motion of the long-short rhythm has been described and often emphasised by the japanese long jump coaches and in the textbook.
The flexion and extension of the knee joint of the support leg tends to generate the greater vertical CG velocity and less horizontal CG velocity. Also, there is the difference in the trunk motion in the takeoff preparation and the takeoff phases between the World and Japan groups. Morinaga et al. (2003) investigated the takeoff preparatory and takeoff motion in good- and poor-jumps for six male long jumpers and found out that the trunk in the good jumps leaned forward at the takeoff and the decrease in the horizontal CG velocity was smaller than in the poor jumps.
These results revealed that long jumpers should keep their trunk lean forward for the takeoff preparation and the takeoff phases.

CONCLUSION: The World group indicated the greater horizontal CG velocity and smaller decrease in the horizontal CG velocity during the takeoff preparation and takeoff than those of the Japan group. The Japan group tended to flex and extend the knee joint of the support leg, and to move the body upward at the L2-off. The trunk of the Japan group got started to lean backward in earlier timing than the World group did.
These motion was likely to cause greater loss of the horizontal CG velocity. Therefore, the long jumpers should keep their trunk lean forward for the takeoff preparation and the takeoff phases. It seemed to be preferable for the Japan athletes to have a motion image of 'Run-though'.

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