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ANALYSIS OF THE TAKEOFF MOTION FOR THE WORLD TOP FEMALE TRIPLE JUMPERS

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The purpose of this study was to investigate the characteristics of the takeoff motion for world-top female triple jumpers by comparing with Japanese university male triple jumpers who have equivalent marks in the triple jump. The subjects were five world top female Jumpers (WF) and four male Jumpers (JM). The motions of the three takeoff phases were videotaped and analyzed (2D motion analysis). The results were as follows; the horizontal CG velocity for WF changed less than that of the JM, implying less braking. WF was characterized by shorter landing distance, forward-leaning trunk and the extended knee joint of the takeoff leg, which may have allowed WF to maintain the horizontal CG velocity and to exert greater leg extension force during the takeoff.

KEYWORDS: triple jump, kinematics, female jumper, motion analysis.

INTRODUCTION: We all know the extreme load that a jumper is exposed during the takeoff in the triple jump (Hay, 1995). This fact raises a question that the takeoff motion of female triple jumpers may be different from that of male jumpers because female jumpers are supposed to present lower muscular strength and power than male jumpers. Therefore, it is mandatory to investigate characteristics of the takeoff motion for female triple jumpers in order to design appropriate coaching methods for female triple jumpers. The purpose of this study was to investigate the characteristics of the takeoff motion for the world-top female triple jumpers by comparing with Japanese university male triple jumpers who have equivalent marks in the triple jump.

METHODS: The subjects were five world-top female Jumpers (WF, record of analyzed Jump: 14.99±0.18m) and four male Jumpers (JM: 15.01±0.19m). WF were videotaped with Peak Motus 3D Pan & Tilt Module (60Hz) at the final of The 2007 World Championships in Athletics, Osaka. JM were videotaped with three high-speed cameras (300Hz) placed on the lateral sides of the three takeoff points. These cameras covered the motions of the three takeoff phases.

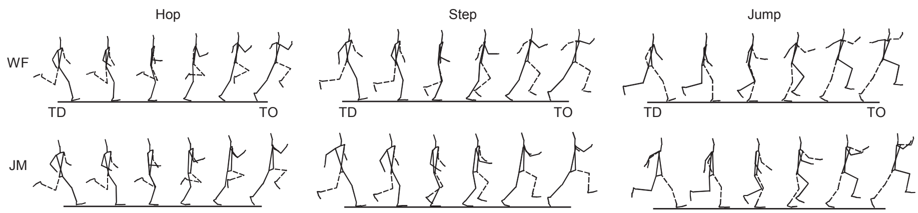

Figure 1: The standard motion model of the WF and JM at the three takeoffs.

Twenty-three segment endpoints were digitized from VTR images, and the coordinates data were smoothed with the Butterworth low-pass digital filter at optimal cut-off frequencies from 9 to 12 Hz determined by residual analysis. The 2D kinematic analysis was used for the calculation of selected biomechanical variables such as velocity of the center of gravity (CG)

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and joint angles. The standard motion model (Ae et al., 2007) was used to compare the takeoff motions of the WF and JM (Figure 1).
The Mann-Whitney's U test was used to assess significant differences between the WF and JM. The level of significance was set at 5%.

RESULTS AND DISCUSSION: At a glance of Figure 1 (standard motion models for the WF and JM) we can notice some characteristics of the WF such as a sprint–like takeoff motion at the hop, forward-leaning trunk and less flexed knee joint of the takeoff leg. The distance ratios for the WF were hop 36.9±0.9%, step 27.3±1.0%, and jump 35.8±0.3%, which is referred to as the balance technique, and those of the JM were 37.9±1.6%, 28.3±1.7%, 33.8±0.7%, as the hop dominated technique. The ratio of the jump for the WF was significantly greater than for the JM ($p<0.05$). The horizontal CG velocity for WF changed less than that of JM.
Tables 1and 2 show CG velocities of the WF and JM at the touchdown (TD) and toe-off (TO) for the three takeoff phases. The change in the horizontal CG velocity during the takeoff phases (ΔHV in Table 1) of the step phase for WF was significantly smaller than JM ($p<0.05$), and deceleration of velocity (V_{dec}) in the first half of the takeoff phase of the hop and step phases for WF were smaller than JM (hop, $p<0.05$; step, $p<0.01$). These results indicated that WF performed their takeoff motion with a the technique enabling to reduce braking. The vertical CG velocity at TD of the jump phase for WF were smaller than for JM ($p<0.05$), which implies smaller impact force for WF.

Table 1
The horizontal CG velocity component of the WF and JM at the Touchdown (TD) and Toe-off (TO) of the three takeoff phases in triple jump.

	Horizontal CG velocity (m/s)														
	Hop					Step					Jump				
	TD	min	TO	ΔHV	V_{dec}	TD	min	TO	ΔHV	V_{dec}	TD	min	TO	ΔHV	V_{dec}
WD	9.22	8.43	8.56	-0.65	-0.78	8.39	7.76	7.88	-0.48	-0.63	7.67	6.49	6.79	-0.88	-1.18
(SD)	0.21	0.23	0.19	0.29	0.27	0.31	0.31	0.12	0.28	0.35	0.23	0.14	0.19	0.36	0.29
JM	9.64	8.30	8.93	-0.71	-1.34	8.94	7.51	8.01	-0.86	-1.42	8.02	6.29	6.87	-1.16	-1.73
(SD)	0.33	0.47	0.33	0.15	0.36	0.21	0.27	0.07	0.17	0.26	0.17	0.41	0.28	0.30	0.48
					*	*			*	**	*				

** and * represent a significant difference between WF and JM, $p<0.01$ and $p<0.05$, respectively

Table 2
The vertical CG velocity component of the WF and JM at the Touchdown (TD) and Toe-off (TO) of the three takeoff phases in triple jump.

	Vertical CG velocity (m/s)					
	Hop		Step		Jump	
	TD	TO	TD	TO	TD	TO
WD	-0.34	2.39	-2.15	1.62	-1.45	2.55
(SD)	0.05	0.16	0.18	0.14	0.26	0.29
JM	-0.71	2.65	-2.47	2.04	-2.07	2.36
(SD)	0.48	0.27	0.27	0.22	0.31	0.27
	*			**	*	

** and * represent a significant difference between WF and JM, $p<0.01$ and $p<0.05$, respectively

Figure 2 shows TD and TO distances of the WF and JM at the TD and TO of the three takeoffs. No significant difference was found in the TO distance between the two groups, but the TD distances at the hop and step phases for WF were shorter than for JM (hop, $p<0.05$; step, $p<0.01$). It can be inferred from these results that WF's takeoff motion was done with less braking, as mentioned before.
Figure 3 shows the trunk and knee angles of the support leg during the three takeoff phases, which was normalized at 100%. Significant differences between the WF and JM are indicated by small circles at the bottom of the figures. During the three takeoff phases, the trunk angle

for WF was smaller than that of JM, indicating a greater forward lean of WF. This may have caused shorter TD distances of the hop and step phases and a smaller decrease in the horizontal CG velocity for WF. There was a remarkable difference in the change in knee joint angle of the takeoff leg between the WF and JM. The knee joint of WF flexed much less than JM. Ae (1982) indicated from the leg extension force data measured in isometric condition that the more the leg is extended, the greater the force exerted. Considering these two results it can be speculated that the takeoff leg for WF could exert greater force during the takeoff.

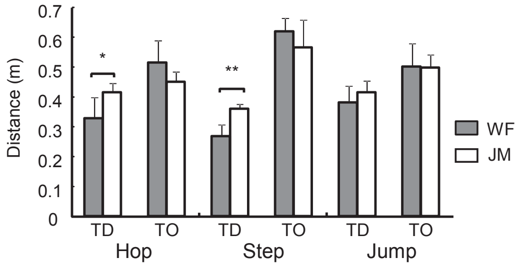

Figure 2: The TD and TO distances for the WF and JM of the three takeoffs. ** and * represent a significant difference between WF and JM, p<0.01 and p<0.05, respectively

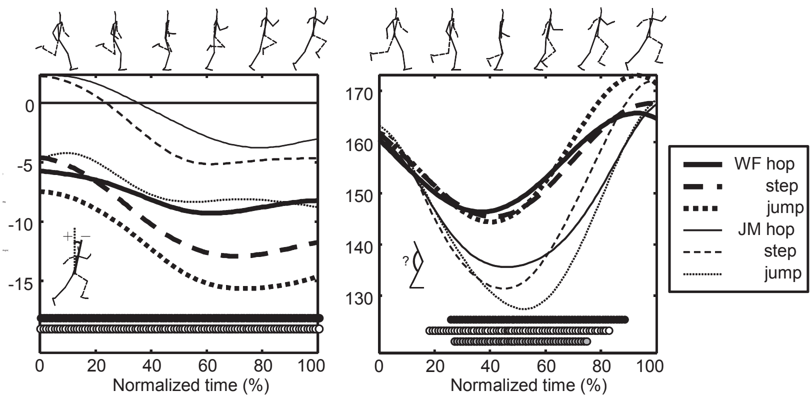

Figure 3: The trunk and knee joint angles of the support leg.
●, ○ and ◎ represent a significant difference between WF and JM, hop, step and jump at p<0.05.

CONCLUSION: The takeoff motion for WF during the three takeoff phases of triple jump was characterized by a shorter landing distance, a forward-leaning of the trunk and an extended knee joint of the takeoff leg, which may have allowed WF to maintain the horizontal CG velocity and to exert greater leg extension force during the takeoff.

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