BIOMECHANICAL ANALYSIS ON TAKE-OFF TECHNIQUE OF CHINESE AND WORLD-CLASS TRIPLE-JUMPERS

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The triple jump is a demanding field event in which a jumper must tolerate extremely high impact forces while maintaining high horizontal speed. The present study was designed to explore the take-off technique how to maintain high horizontal speed and achieve optimize effect in the hop, step and jump phases. The best performance of 8 China triple-jumpers (mean performance was 16.01 m) were videotaped and analyzed. This paper compared the parameter with the technique of 18.29 m jump of Edwards in the 1995 WAC. The results showed that bigger push-off angle at toe off resulted in a high angled trajectory in the hop phase and increasing amortization difficulty of the step phase; earlier knee-bend made for less braking angle and loss of horizontal velocity; in the step and jump phase. Chinese jumpers bend the landing knee actively to lessen the forces from landing but delayed the drive into the push-off phase.

KEY WORDS: triple-jump, take-off, amortization, push-off, land, biomechanical analysis

INTRODUCTION: The triple jump is a demanding field event in which a jumper must tolerate extremely high impact forces while maintaining high horizontal speed. The execution of triple-jump performance rests with the transition capacity from high run-up speed to consecutive jumps for the greater part. This study examined how to utilize run-up speed and decrease the loss of horizontal velocity in the hop, step and jump phases of the triple jump. Secondly, we examined the difference between a world-class triple-jumper (Jonathon Edwards) and a group of Chinese jumpers in take-off technique.

METHODS: During a Track & Field tournament of China in Ningbo city in 2001, the researchers videotaped the final of the men's triple jump. The hop, step and jump were recorded by two separate digital videos (Panasonic GS11). The frame rate is 60 fields per second. The best performance of 8 Chinese triple-jumpers (mean performance was 16.01 m, range from 15.74 m to 16.43 m) was analyzed by using Motion Analyze Tools version 1.1a. For purposes of comparison, the parameters of the technique of the 18.29 m jump of Jonathon Edwards from the World Athletics Championships in 1995 were used (Lu & Wang (2004), the internet website www.biomechanics.mai.ku.dk).

RESULTS AND DISCUSSION: Table 1 shows the difference between a world-class jumper (Edwards) and Chinese jumpers in horizontal velocity (Vx) and vertical velocity (Vy). In jump phase, the Vx3 of Edwards is 7.80 m/s, 81.25% of Vx1, while mean Vx3 of 8 Chinese jumpers is 6.40 ± 0.20 m/s, 69.6% of Vx1, respectively. Vy3 of Chinese jumpers is close to Edwards. It shows that Chinese jumpers decrease more horizontal velocity after two sequential hop and step.

Table 1 Horizontal velocity and vertical velocity of hop, step and jump.

Unit: m/s	Vx1	Vy1	Vx2	Vy2	Vx3	Vy3
China (n=8)	9.20±0.17	2.36±0.12	7.93±0.40	1.76±0.16	6.40±0.20	2.41±0.17
Edwards	9.60	2.75	9.10	2.07	7.80	2.44

Table 2 shows that the Chinese jumpers spend more time in the braking phase to amortization of the force from the landing that results to lose more horizontal velocity. However, in the push-off phase they shorten the push-off time so lose drive from the landing force.

Table 2 Supporting time parameters of hop, step and jump.

Unit: s	Jonathon Edwards			China (N=8)		
	Hop	Step	Jump	Hop	Step	Jump
Braking-time	0.039	0.039	0.06	0.05	0.07	0.08
Push-off time	0.06	0.06	0.081	0.04	0.06	0.06
Total time	0.099	0.099	0.141	0.09	0.13	0.14

Table 3 Kinematic parameters during the hop, step and jump phases.

Unit: °	B-A(Hop)	P-A(Hop)	B-A(Step)	P-A(Step)	B-A(Jump)	P-A(Jump)
China(n=8)	66.13±1.57	66±1.91	64.4±2.12	55.16±1.21	62.28±0.99	58.27±1.14
Edwards	69.27	62.71	73.5	68.28	70.60	69.15

B-A: braking angle, the angle between horizontal line and the line from heel to CM at the moment of heel-strike; P-A: push-off angle, the angle between horizontal line and the line from heel to CM at the moment of toe-off.

Table 4 Knee angle of hop, step and jump.

Unit: °	Jonathon Edwards			China (N=8)		
	Hop	Step	Jump	Hop	Step	Jump
Braking-knee-Angle	166.4	168.1	173.1	153	155	149
Minimum-knee-Angle	147.3	133.2	136.9	134	118	126
Transform-knee-Angle1	19.2	34.9	36.2	19	37	23
Push-off knee-Angle	177.9	177.2	177.1	147	150	164
Transform-Knee-Angle2	30.6	44.0	40.2	13	32	38

Transform-knee-Angle1: Braking-knee-Angle minus Minimum-knee-Angle,
Transform-Knee-Angle2: Push-off knee-Angle minus Minimum-knee-Angle.

To maintain high horizontal speed throughout the triple jump, the theoretic braking angle should be closer to 90° (Jarmo, 2000). Former study figures out the model of braking-angle (B-A) of hop, step and jump should be 69° ± 3°, 68° ± 2°, 66° ± 2° (Li & Sha, 2001), respectively. At the moment of heel landing, Chinese jumpers take forward bending-knee motion, the braking angle (B-A) of hop, step and jump touch bottom of model value which influence the velocity of the CM moving over the supporting foot so that supporting time prolongs, B-A of hop, step and jump of Edwards come to a head of model value which helps to maintain horizontal speed. On the other side, bigger Braking-knee-Angle implies the jumper has the ability of tolerating high ground reaction forces. Table 4 shows that 8 Chinese jumpers take forward bending-knee action to amortize ground reaction forces, the braking-knee-angle of hop, step and jump less than that of Edwards. From braking phase to maximal amortization phase, Transform-knee-Angle1 of Chinese jumpers is close to that of Edwards, but the braking time of Chinese jumpers is longer, so the amortization efficiency less than Edwards.

To acquire vertical velocity and horizontal velocity in push-off phase, the athlete should make optimal use of driving forces. In the maximal amortization phase, the Minimum-knee-Angle at the range135° - 145° could make for drive to push-off. Eight Chinese jumpers are difficult to drive their strength while the knee angle (147.3°, 133.2°, 136.9°) favors Edwards driving to push off (Table 4). The Push-off knee-Angle and transform-Knee-Angle2 reflect the driving status (Table 3 and Table 4). Compared with Edwards, to shorten their push-off time, Chinese jumpers lose their push-off strength.

CONCLUSION: Chinese jumpers lose more velocity compared with Edwards. From a biomechanical viewpoint, 8 jumpers' amortization technique and driving capacity influence the performance. A larger push-off angle at toe off resulted in a high angled trajectory in the hop phase and increasing amortization difficulty of the step phase; earlier knee-bend made for less braking angle and loss of horizontal velocity. In the step and jump phases, Chinese jumpers bend the knee forwardly to less the forces from landing but delay to drive in push-off phase.

Biomechanical analysis by using videotape and Motion Analyze Tools could help to detect the difference between sub-elite jumpers and a world-class jumper. The Chinese triple-jumpers in this study should develop technique according to the take-off structure and improve power training in a scientific manner.

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