BIOMECHANICAL ANALYSIS OF ELITE CHINESE FEMALE POLE VAULTERS' TAKE-OFF TECHNIQUES

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Takeoff is one of the most critical phases used to determine pole-vaulting performance. The purpose of this study was to study the takeoff in pole-vaulting of Chinese female athletes. A National M9500 video camera was used to record subjects' performance at a frequency of 25 frames per second. The videos were digitized by stma10 video analysis system developed by Engine Body Information. Kinematics data including the take-off velocity, time, position and angle was calculated. Comparing the Chinese subjects with world elite athletes, all athletes that were studied, should increase horizontal absolute velocity and plant the pole at an earlier time. The take-off angle should be reduced to the proper value of 20°. Also, these athletes should limit the backward leap of the trunk in order to prevent the hip joint angle from becoming excessively large. Free takeoff technique should be adopted.

KEY WORDS: take-off, plant

INTRODUCTION: Takeoff is one of critical phases in pole vault. It immediately follows the run-up and greatly influences aerodynamic movements. Effective and scientific takeoff, which maintains or even increases the energy gained from run-up to its maximum, is an indispensable requirement for successful performance.

METHODS: Video analysis method was adopted in this study. A National M9500 video camera recorded the subjects' performance at a frequency of 25 frames per second. The video camera was placed 30m away from the movement course at a height of 1.2m. The videos were digitized by stma10 video analysis system developed by Engine Body Information Research Institution at an operating frequency of 50 Hz. The body model was Zatsiorsky model. All data was smoothed by the digital filter with a cut-off frequency of 8.

RESULTS: The changes of velocity during takeoff: The subjects for this study included 6 female Chinese athletes. The results obtained indicated that their mean value of loss in horizontal velocity during takeoff was 1.547 m/s and their mean horizontal velocity was 6.182 m/s at the moment when the takeoff foot lost contact with the ground. The ratio between these two values was 0.250, while this ratio was 0.139 and 0.19 for (athlete V.) and (athlete B.) the world's top male vaulters, respectively. This means that the loss in horizontal velocity at takeoff is comparatively high for Chinese female vaulters. Their mean vertical velocity increased 2.901 m/s during takeoff and its ratio with the horizontal velocity at the moment the takeoff foot lost contact with the ground is 0.469, whereas that of athlete V. was 0.28 and that of athlete B was 0.34. This indicates that the vertical velocity at takeoff was too high for Chinese female vaulters. Among the subjects in this study, athlete W. C. has the smallest value of loss in horizontal velocity, 0.19 m/s and increment of vertical velocity during takeoff 0.41. Therefore, her takeoff technique is the most scientific.

Plant and takeoff time. Takeoff time is the time of the duration form the moment takeoff foot contacts the ground to the moment its breaks contact with it. Chinese female athletes' takeoff time, mean value as 0.12 second, are comparatively short and almost the same as that of athlete B.

Elite athletes plant the pole rather early and they usually regard the moment in the second half of takeoff when the body moves upward and forward and only the toes contact the ground as the best time for the plant. They even adopted the technique to takeoff before plant. This means takeoff is completed before the butt end of the pole contacts the box and the plant usually is done as the athlete is in the air. This takeoff technique not only can help decrease the energy loss caused by early bend of the pole but also can increase work done during takeoff by a longer displacement in horizontal and vertical direction. Among the study subjects, athlete W. C. is the one that has a good command of this technique. Other athletes

all planted the pole before jump (Detailed parameters are listed in Table 2I). The time variation between the takeoff and the plant is –0.02 second for athlete W.C., 0 for athlete H. Y. and positive values for other subjects.

Table 1 The Changes of Velocity During Takeoff

Name	When the takeoff foot contact the ground		When CM is at the lowest position		When the takeoff foot break contact with the ground		Loss in horizontal velocity	Increase of vertical velocity	Vx(loss)/Vx(break)	Vy(increase)/Vx(break)
	Vx	Vy	Vx	Vy	Vx (break)	Vy (break)	Vx (loss)	Vy (increase)		
Weiyan Cai	7.660	-0.034	6.752	1.752	6.415	2.521	1.245	2.555	0.194	0.398
Caiyun Sun	7.828	-0.046	6.633	1.635	6.044	2.661	1.784	2.707	0.289	0.448
Xiaoming Peng	7.721	-0.195	6.686	1.392	6.300	2.785	1.421	2.980	0.226	0.473
Honglin Yang	7.642	-0.190	6.803	1.048	6.412	2.498	1.230	2.688	0.192	0.419
Na Zhang	7.575	-0.023	6.782	1.202	6.012	2.843	1.563	2.857	0.132	0.475
Junmei Tang	7.952	-0.426	6.746	1.425	5.911	3.191	2.041	3.617	0.345	0.612
Average value	7.730	-0.152	6.734	1.409	6.182	2.750	1.547	2.901	0.250	0.469
Volkov					7.86		1.09	2.24	0.139	0.28
Bruka					8.20		1.57	2.80	0.19	0.34

Table 2 The Changes of Kinematic Parameters During the Plant and Takeoff Phase

Name	Takeoff time	The time variation between the takeoff and the plant	Take off angle	The distance between the takeoff position and the box	
Weiyan Cai	0.12	-0.02	21.45	3.397	34.50
Caiyun Sun	0.10	0.06	23.76	3.042	34.04
Xiaoming Peng	0.12	0.04	23.85	3.233	34.34
Honglin Yang	0.12	0	21.28	3.321	35.17
Na Zhang	0.10	0.08	25.24	3.098	35.92
Junmei Tang	0.14	0.02	28.36	3.202	36.50
Average value	0.12	0.03	23.99	3.216	35.08
Volkov			17.5		
Bruka	0.12		19		

Takeoff angle and the takeoff position. Most takeoff angles of the female subjects are in the range from 21°to 28°, while they were 21.45° for W. C. and 21.28°for H. Y. Other athletes' takeoff angles were larger and ranged from 23.76°to 28.36, whereas the world top male athletes' average value is 18.5°(Table-II). This indicates that the takeoff angles of elite Chinese female vaulters are overly large and this will make the following pole bend and pole erections suffer.

In order to prevent body from leaning backward and arm's from moving backward, elite athletes not only have muscular strength in trunk, shoulder and arms, they also should be encouraged to takeoff well before the box. One example of that position is 4.50m in front of the box observed in Track & Field World Championship in 1995. Among the study subjects, only W D. and H. Y. had a relatively long distance between the takeoff position and the box,

3.397m ad 3.321m respectively.

The changes of pose during takeoff. Unlike other exercises, in the pole vaulting, knee joint angle is comparatively large during cushioning phase and the hip joint angle increases in the last two steps before the takeoff. This increase of angle is 5° for W. C. and more than 20 ° for other subjects. The reason for this increase partly lies in the increased backward leap of the trunk. Excessive backward leap of the trunk will not only impede the takeoff and the body swing, but also be detrimental to athletes' adopting the technique to takeoff before the plant. At the very moment of the plant and takeoff, the trunk should be kept upright, and at the same time the arms, shoulders and trunk should be kept straight, upper extremities vertically extended. But it is not the case of the higher the upper extremities are extended, the better is the performance. Especially at the moment the pole collides the back of the box, slight flexion of the arms is permitted, since this could decrease the loss in the strain energy stored in muscles, ligaments and tendon.

Table 3 Body Positions When the Take-off Foot Broke Contact with the Ground

Name	Knee joint angle	Hip joint angle	Left elbow joint angle	Right elbow joint angle
Weiyan Cai	149.45	171.03	142.58	145.43
Caiyun Sun	159.74	184.22	138.13	153.34
Xiaoming Peng	156.82	186.53	154.28	163.25
Honglin Yang	168.91	188.32	101.61	157.68
Na Zhang	157.81	184.64	135.65	153.68
Junmei Tang	170.87	199.93	143.64	147.61

CONCLUSION:

The plant and takeoff are the most important phases in pole vault. These phases have great influence on the vaulter's movement over the bar and the bar clearance. Nowadays, many female athletes have learned the free takeoff, i.e. the vaulter's takeoff foot loses contact with the ground before the tip of pole touches the back of the box. Also with the increase of the athletes speed of run-up, their distances between the takeoff position and the box are increasing, though many still have a long way to go when compared with male athletes. To increase this distance, hands should be held higher on the pole and this in turn will demand a higher run-up velocity.

1. All athletes should increase horizontal absolute velocity as much as possible in order to increase the horizontal moment at the takeoff. The loss in horizontal velocity during takeoff should be reduced and increase of vertical velocity should be appropriately limited.

2. All athletes should consider planting the pole at a suitably early time during the plant phase and lowering their poles right before the last two steps.

3. Small takeoff angle should be adopted and 20°is a proper value. Among elite Chinese women athletes, the takeoff angle is too big.

4. All athletes should properly limit their back leap of the trunk during takeoff and prevent the hip joint angle from being excessively large. Free takeoff technique should be adopted.

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