

## BIOMECHANICAL ANALYSIS OF THE TOP CHINESE FEMALE POLE VAULTERS

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Take-off skills in the pole vault are very important to the total performance, and incorrect take-off technique will greatly affect the energy transition and the work on the pole. The movements on the pole directly determine the effect of bar clearance. The aim of this study was to improve the women's pole vaulting technique, using biomechanical analysis on these phases.

**KEY WORDS:** pole-vaulting, take-off, biomechanical analysis.

**INTRODUCTION:** Chinese female pole vaulters performed well in 1990's with some world class performances. Caiyun Sun's pole vaulting technique was analyzed in 1997 (Horst Adamczewski, 1997; Stefanic Grabner, 1997), however, there have been few studies on the techniques of other high level Chinese female pole-vaulters.

**METHODS:** Seven top Chinese female pole-vaulters were videotaped in 1999. The recording was conducted using a National video camera M9500 (25Hz), and the data were acquired by an AJIE video analysis system.

**RESULTS AND DISCUSSION:** The hip angle increases at the point of breaking contact with the ground compared with the second-last step. The value should be small according to Weiyang Cai (about 5°), while for other athletes in this study this value was over 20°. This increase in hip angle contributes to the body rotation backward around the waist at the last two strides, which causes some negative effects to the following movement. This is not a good body position for athletes to use during the technique of planting after the take-off. Therefore, pole-vaulters should keep the trunk upright at the take-off moment and plant, in addition to keeping the upper limb musculature in a state of tension whilst the arms are fully extended. Furthermore, the moment the pole touches the back of the box the upper limbs should bend slightly in order to minimize the elastic potential energy loss.

Table 1. Joint Angles at take-off .

Name	Knee	Trunk-leg	Left elbow	Right elbow
Weiyang Cai	149.5	171.0	142.6	145.4
Caiyun Sun	159.7	184.2	138.1	153.3
Xiaoming Peng	156.8	186.5	154.3	163.3
Hongling Yang	168.9	188.3	101.6	157.7
Na Zhang	157.8	184.6	135.7	153.7
Junmei Tang	170.9	199.9	143.6	147.6
Shuying Gao	175.4	205.2	103.9	166.6
<b>Average</b>	<b>162.7</b>	<b>188.5</b>	<b>131.4</b>	<b>155.4</b>

A correctly timed upswing is very important to bend the pole after the plant. Athletes should strengthen their arms and shoulders to assist with this (Table 1). During the pendulum and upswing, the arms control the center of the CM. The right arm takes the function of supporting the body mass, while the left arm performs a establishing function. This is called the first upswing phase from the pendulum movement to the rock-back, and the second upswing phase is defined by the rockback until body extension. Upswing initiates the start of work on the pole, which is very important to the following movements such as extension and bar clearance. Athletes must rotate the body and then extend the trunk smoothly for successful completion of it. High level athletes tend to rock-back faster than those who do not jump as high, and some Chinese athletes show no free flight phase after the bar

clearance, as the legs have fallen towards the bar after the rock-back, so they cannot reach a desirable height after upswing. Duration of the first upswing and second upswing phases are shown in Table 2.

**Table 2.** Upswing duration.

Name	First Upswing (s)	Second Upswing (s)
Weiyang Cai	0.40	0.42
Caiyun Sun	0.42	0.56
Xiaoming Ping	0.40	0.46
Hongling Yang	0.40	0.60
Na Zhang	0.40	0.48
Junmei Tang	0.52	0.34
Shuying Gao	0.44	0.34
<b>Average</b>	<b>0.43</b>	<b>0.46</b>

The phases of the pole-vault include pendulum, upswing, body extension, turn and bar clearance. Work on the pole of the female vaulters has much potential of being improved.

**Table 3.** Partial height analysis.

Name	H <sub>1</sub>	%	H <sub>2</sub>	%	H <sub>3</sub>	%	H <sub>4</sub>	%	H
Weiyang Cai	1.045	25.5	3.129	76.3	0.005	0.1	0.079	1.9	4.10
Caiyun Sun	1.083	26.4	3.016	73.5	0.004	0.1	0.003	0.1	4.10
Xiaoming Peng	1.064	26.3	3.068	75.7	0.029	0.7	0.111	2.7	4.05
Hongling Yang	1.083	28.5	2.731	71.9	0.139	3.6	0.153	4.0	3.80
Na Zhang	1.155	31.2	2.669	72.1	0	0	0.124	3.3	3.70
Junmei Tang	1.137	29.9	2.801	73.7	0.047	1.2	0.185	4.8	3.80
Shuying Gao	1.200	32.4	2.638	71.3	0.028	0.8	0.166	4.5	3.70
<b>Average</b>	<b>1.110</b>	<b>28.6</b>	<b>2.865</b>	<b>73.5</b>	<b>0.036</b>	<b>0.929</b>	<b>0.117</b>	<b>3.043</b>	<b>3.893</b>

H<sub>1</sub> indicates take-off height of the CM.

H<sub>2</sub> indicates the difference in height of the CM between the last ground contact of the take-off foot and the moment of release of the pole.

H<sub>3</sub> indicates free flight height of the CM.

H<sub>4</sub> indicates height of the CM above the cross-bar.

From Table 3 it can be seen that in the case of these 7 athletes, H<sub>1</sub> varies between 1.045 m and 1.155 m, which is mostly determined by an athlete's height. We can see that Weiyang Cai's H<sub>1</sub> was 1.045 m, while Na Zhang's displayed a value of 1.155 m. H<sub>2</sub> contains a very large proportion of the final height jumped, so it is worth discussing. Weiyang Cai, Caiyun Sun and Xiaoming Peng were over 3m, while other vary between 2.6m and 2.8m. In the case of Weiyang Cai (who displayed the greatest H<sub>2</sub>), it was 76.3% of the height jumped, while 71.3% was the poorest (Shuying Gao). H<sub>3</sub> did not show large values in these female pole-vaulters (the maximum was 0.139 and the minimum was 0). There was no real flight phase, as the vertical velocity was zero or less than zero at the moment of the bar clearance. H<sub>3</sub> in this group of female pole vaulters there is a difference from male world class pole-vaulters. For example, in the case of Sergey Bubka, he displays an H<sub>3</sub> of 0.85m, and he shows a high vertical velocity of the CM at the moment of the bar clearance (Yanxi Wu, 1987). As far as Chinese female athletes are concerned, all the bar clearance values were less than zero. (Table 4)

**Table 4.** Velocity from Take-off to Bar Clearance (m/s).

Name	Take-off point	“Plant point”	Start of “upswing”	“Rockback”	Full extension	Bar clearance point
Weiyao Cai	2.5	2.7	1.5	1.7	3.6	-0.3
Caiyun Sun	2.7	0.9	2.3	2.3	2.8	-0.3
Xiaoming Peng	2.8	2.0	1.8	2.4	2.9	-0.9
Hongling Yang	2.5	2.5	2.7	2.0	2.5	-1.7
Na Zhang	2.8	0.5	2.2	2.5	2.4	0
Junmei Tang	3.2	3.2	2.6	2.2	3.2	-1.2
Shuying Gao	2.5	2.4	2.0	2.7	2.1	-0.5
<b>Average</b>	<b>2.7</b>	<b>2.0</b>	<b>2.2</b>	<b>2.3</b>	<b>2.8</b>	<b>-0.7</b>

At take off Bubka can get into a good body position, which enables the energy stored in the pole to be returned in the form of vertical acceleration of his CM. Women pole vaulters should swing and rock back faster and avoid pushing off the pole only in the horizontal direction. If they can get into a good position after extension, it may be possible for them to gain additional height after the release of the pole.

**CONCLUSION:** Athletes should control the body position during the take-off phase to avoid an improper hip angle. The technique of plant after take-off is also recommended. A successful second swing depends upon shortening the radius of rotation of the body and lifting the hip joint rapidly. Some Chinese pole-vaulters, at the point of the second swing, pointed their body's to the bar directly when extending it instead of lifting the hip joint, so the height achieved was greatly decreased. The potential of improving techniques at the phase of over pole is greater to the female. Out of all heights mentioned above  $H_3$  (from the phase of pushing the pole to the phase at which the CM is the highest) is meaningless for most female vaulters, because their vertical velocities are either mostly zero, or less than zero, at the phase of pushing the pole.

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