

BIOMECHANICAL ANALYSIS OF VERTICAL JUMP PERFORMANCE OF VOLLEYBALL PLAYERS

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The purpose of this study was to provide some reference in the vertical jump performance of professional volleyball player. It was expected that, the main biomechanical factors relative directly to the jump height of professional volleyball player can be found through the synchronic test of ground reaction force and video technique performance.

KEY WORDS: volleyball, vertical jump performance, biomechanics

INSTRUCTION: As a basic form of jump, the vertical jump performance (VJP) has been studied by researchers for decades. Recently, a large body of literature has been published in this field. According to James J. Dowling and Lydia Vamos (1993), the jump height is highly related to the maximum positive power ($r=.928$, $p<.01$), and also related to the maximum force ($r=.519$, $p<.01$). Armin Kibele (1998) addressed an article regarding a methodological point in standard test of VJP in Laboratory. Luis F. Aragon-Vargas and M.Melissa Gross (1997) furnished us a 4-lever biomechanical variable system to research VJP. The work of these scientists provided us some aspects to understand the mechanism of VJP. However, few articles use the professional volleyball players directly as research subjects. The purpose of this study is to submit some reference in the VJP of professional volleyball player. It is hoped that, the main biomechanical factors relative directly to the jump height of professional volleyball player will be found through the synchronic test of ground reaction force and video technique performance.

METHODS: 5 Chinese professional male volleyball players with national level, age 22.5 ± 3.8 , height $1.94\pm .06$ m, weight 74.2 ± 4.9 kg, were selected to perform the vertical jump in Biomechanics Laboratory. In order to simulate the real jump performance during the volleyball competition, each player was instructed to complete 2 maximum vertical jumps with arm swing from a static, upright posture. Because of a mistake about the recording, only 9 VJP were recorded in Kistler platform system in 200Hz for ground reaction force and synchronically videotaped with PANASONIC AG-DP200E recorder in 50Hz in sagittal plane. The distance from focus was about 10m. The height of the focus is about 1.4m. The video pictures were digitized and analyzed on Engine Video Analysis Performance System. A second-order Butterworth digital filter was used to smooth the derived data with cutoff frequency 8Hz for displacement variables (angular and linear displacements) and 6Hz for velocity variables (angular and linear velocities). The final data were dealt statistically ($n=9$)

Glossary of Terms

H_d --- downward motion of CM relative to static, upright posture (m).

H_j --- jump height of CM relative to static, upright posture (m).

W --- body weight (kg)

V_y --- the maximum vertical velocity of CM (m/s).

V_{hand} --- the maximum velocity of hand (m/s).

P_0, P_1, P_2 --- the negative maximum force, the first positive peak of force, and the second positive peak of force (N).

p_0, p_1, p_2 --- the rate of P_0, P_1, P_2 over W .

I_1, I_2 --- the impulse of ground reaction including the body weight (Ns).

T_0, T_1, T_2 --- the time of P_0, P_1, P_2 point relative to the datum line (ms)

T_S, T_H, T_K, T_A --- the time when the joint of shoulder(S), hip(H), knee(K), ankle(A) begin to accelerate relative to the datum line (ms).

T_a --- the time of the acceleration phase (ms)

T_n --- the time of no acceleration phase during the takeoff period (ms).

ω --- the maximum joint angular velocity (deg/s).

RESULTS AND DISCUSSION: The ground reaction force: The variables about ground reaction forces of all subjects are presented in Table 1. The correlation r in this Table means the correlation with the jump height of CM. It is shown that the lost weight in the downward motion is about half of body weight, while the maximum positive force is 1.77 times of body weight.

The typical force-time curve of VJP is a double peak curve. The first peak P_1 is shown the greatest correlation ($r = .87, p < .01$). The second peak of force is also correlated with the jump height but with less correlation coefficient ($r = .69$). This implies that the first peak of force has closer relationship to the jump height than the second one. This phenomena seemed to be opposite to the conclusion of James J. Dowling and Lydia Vamos (1993): "the five worst jumps seemed to be characterized by a double peak of force in the positive impulse phase compared to the five best jumps, which seemed to have only one." (p.104).

Table1 The Variables of Force-Time Curve

	P_0	P_1	P_2	p_0	p_1	p_2	I_1	I_2	T_0	T_1	T_2
Mean	-382.8	1039.4	1286.7	-.52	1.43	1.77	-69.3	331.5	552.8	286.7	103.9
SD	101.7	174.4	217.5	.12	.18	.18	25.7	43.2	72.3	32.1	14.1
R	-.05	.87*	.69	-.24	.77*	.51	-.27	.86*	-.1	-.3	.1

Note. * $p < .01$.

The positive ground reaction impulse I_2 is 331.5 ± 43.2 NS with just as high correlation as the first peak of force. The negative impulse I_1 with the mean value -69.3 NS shows the characteristic of great dispersion. The force-time curve of some performances is too irregular in negative impulse for us to read the force impulse data correctly.

The sequence of joint acceleration: Regarding the sequence of the joint rotational acceleration of volleyball player, it is revealed in figure 2 that the shoulder is first, the hip

second, then the knee and the ankle last. The mean of the time variables is listed in Table 2. The shoulder joint begins acceleration at .59s, but ends at .39s, which means that from .39s to the datum line the shoulder has no rotational acceleration. It is clear that the shoulder is isolated with the other joints when making acceleration. Also the hip joint is double accelerated during the takeoff phase. Within the period of .29s, there is the short period (about .08s) during which no joint angular acceleration is found at the hip joint.

The kinematic variables: The motion of CM is presented in Table 3. The downward motion of CM is seemed very deep with the mean value $.446 \pm 0.041$ m, which is high negatively related to the jump height ($r = -.84, p < .01$). The peak of vertical velocity with the mean value 3.409m/s is emerged at datum line. Because of the arm wave during the takeoff, the hand produced great velocity with the peak value 12.8 ± 1.3 m/s. This hand peak of velocity shows high correlation ($r = .83, p < .01$) with jump height.

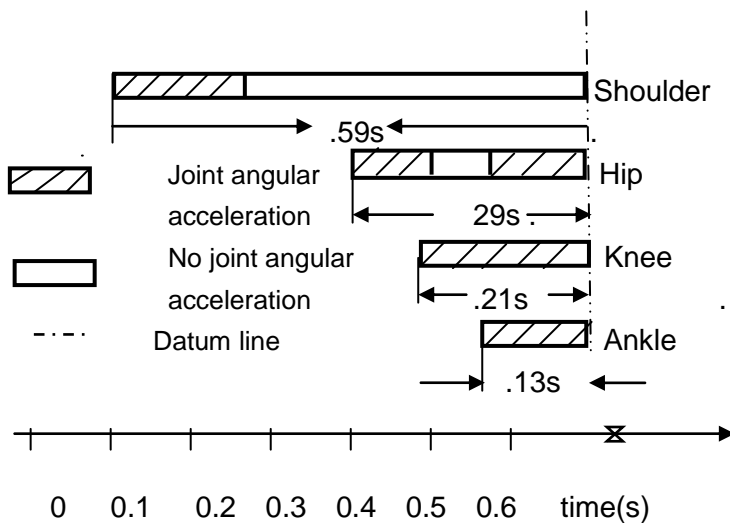


Figure 2 - The sequence of the joint angular velocity rotational acceleration.

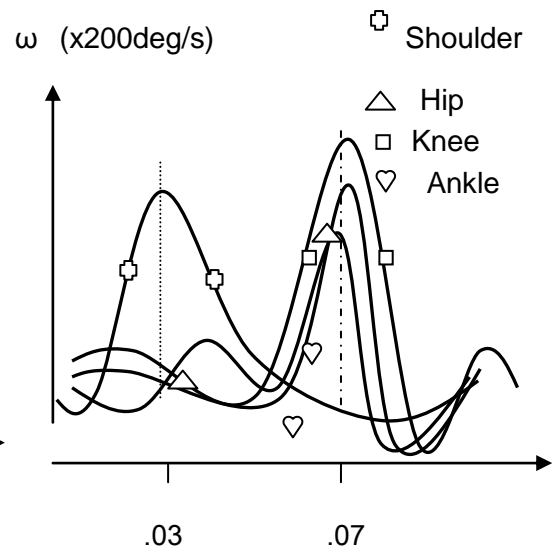


Figure 3 - Typical joint of VJP of volleyball player.

In aspect of joint rotation, all joints except the shoulder are on the positive peak of angular velocity at the point of datum line (see Figure 3). This implies that the volleyball players have high ability to be coordinate in joint acceleration comparing to the other subjects (Xinhai Shan, et al., 1997).

Table 2 Time Variables of Joint Angular Acceleration

SHOULDER			HIP				KNEE		ANKLE	
T_a	T_n	T_s	T_{a1}	T_n	T_{a2}	T_H	T_a	T_K	T_a	T_A
.20	.39	.59	.11	.08	.1	.29	.21	.21	.13	.13

Table 3 **Biomechanical Variables**

Variables	V_{hand}	V_y	ω_s	ω_{H1}	ω_{H2}	ω_K	ω_A	H_d	H_j
Mean	12.8	3.409	831. 0	264.3	626.3	888.6	755.3	.446	.593
SD	1.3	.16	98.7	36.9	53.3	66.6	84.8	.041	.033

Note: The velocities and angular velocities are the maximum values.

CONCLUSION: On the VJP of professional volleyball player, the double peak of force is shown on the force-time curve. The first peak has higher relative to the jump height than the second one though the first peak force is lower than the second peak force. In aspect of the joint rotation, first the shoulder emerges the acceleration, then the hip, next the knee and the last the ankle. Unlike the other joints that emerge the acceleration just in period of upward phase, the shoulder emerges the acceleration mainly in the downward phase. The hip has double rotational accelerations rather than continuous speed up rotation. Further more, the peak of arm waving velocity is high positive correlate with the jump height. Every joint except the shoulder seems to be highly coordinated to reach the maximum angular velocity at the liftoff point. It is clear that, the powerful wave of arm, the high strength of hip joint with short downward motion of CM are much more helpful to improve the joint height.

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