KINETIC AND KINEMATIC DIFFERENCES OF TWO VOLLEYBALL-SPIKING JUMPS

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The purpose of this study was to investigate the net muscle moments and work on the lower limbs in two different volleyball-spiking jumps by inverse dynamics. A Kistler force platform (600 Hz) was synchronized with a Peak high speed camera (120Hz) to collect the volleyball jumping action. Sixteen volleyball players (8 males and 8 females) were the subjects of the study. The results revealed that the work done in knee joints during eccentric contraction were greater than ankle and hip joints in both two volleyball jumps. In addition, the hip has a greater work contribution on both hop and step-close jump.

KEY WORDS: volleyball-spiking jump, inverse-dynamics.

INTRODUCTION: The volleyball-spiking jumps influence the height of spike and the balance of body in the flight phase. So the spiking jump is the important technique of volleyball spiking. Spike-jumping techniques will vary considerably according to factors such as the weather a hop jump (the feet step upon the ground simultaneously) or step-close jump (one foot steps upon ground, then the other foot) (Coutts, 1979), and approach speed and lengths of the last stride employed. Researchers have studied the effect of approach speed by designing different numbers of approach steps (Kayambashi, 1977) and last step length (Liu & Huang, 2001). Generally, male players prefer step-close jump, and female players prefer hop jump during volleyball-spiking jump take-off. Coutts (1979) studied volleyball hop jump and step-close jump during spiking jump take-off, he only reported the kinetic data and lack of kinematic data. The purpose of this study was to investigate the muscle moments and works on lower limbs in two different volleyball-spiking jump take-off.

METHODS: Sixteen volleyball players (8 males [height: 184.2±5.12 cm, body weight: 79.3±7.3 kg], 8 females {height: 171.5±5.66 cm, body weight: 63.8±4.56 kg]) volunteered as participants. After a warming up and stretching period, each subject performed hop jump take-off and then step-close jump take-off on a Kistler force platform(600 Hz). A Peak high speed camera was positioned perpendicularly 10 m from the subject and synchronized with a force platform to record the spike jump take-off action. A motion analysis video system (Peak Motus) was used to digitize the locations of five anatomical body landmarks (toe, ankle joint, knee joint, hip joint and shoulder joint). The raw data were smoothed with a four-order zero-log Butterworth low-pass filter. Net joint forces and moments were calculated following a standard inverse-dynamics approach. The segmental moments of inertia were estimated using the data presented in a previous study (Dempster, 1955). A standard t-test for paired comparison was used to test for differences between hop and step-close jump. The significant level was at 0.05. The significant level was found between two different jump take-offs, the effect size and power are reported in the tables.

RESULTS AND DISCUSSION: Table 1 listed the selected variables of the hop and step-close jump take-off. The jump height was defined as the difference from take-off height to the highest of center of mass (CM). The takeoff time was defined as the time of the foot on the force platform. The push-off time was calculated from the frame when the body CG at lower point to take-off. There was a significant difference between hop jump and step-close jump on take-off time. The step-close jump had a longer take-off time than the hop jump, which was due to the fact that the subject stepped only one leg on the plate, then followed by the other foot, which increased take-off time. No difference was found between two jumps on jump height and push-off time. Table 2. listed the joints angle, moment and work for two volleyball-spiking jumps. Figure 1 and 2 showed the moment and power of ankle, knee and hip of two jumps for one male subject. The net muscle joint moment and power were based on Winter's (1990) definition. Moments can be used to determine the extensor and flexor's dominance at any given time for the joint contraction.

Table 1. Selected variables in two volleyball jumps.

Variable	Hop-jump	Step-close	Effect size	Power
Jump height (cm)	46.1±8.9	46.6±10.3		
takeoff time (ms)	316.3±49.1	352.5±81.1*	0.64	0.92
push-off time (ms)	191.2±28.1	195.6±32.0		

Note. *Statistical significant difference between hop and step-close jumps.

The negative and positive power indicated that if the dominated muscle groups are under eccentric or concentric contraction, works done at ankle, knee and hip joints were calculated by the following formula:

$$w_i = \int |p_i| \, dt$$

w_i: The absolute mechanical work.

p_i: The muscle power.

By the definition, the moments of flexor in ankle, extensor in knee, flexor in hip are positive, and the power of concentric contraction is positive.

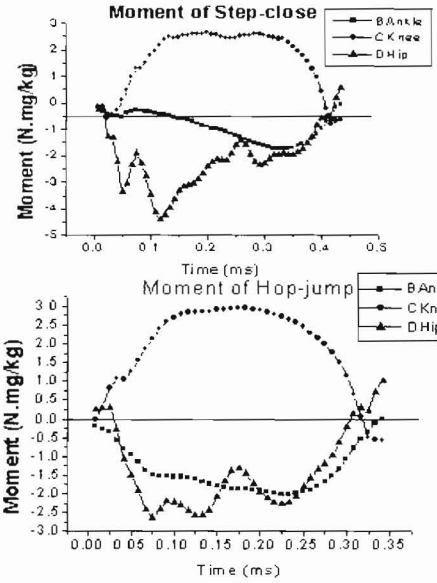

Figure 1. The moment curve of one typical subject in hop and step-close jumps.

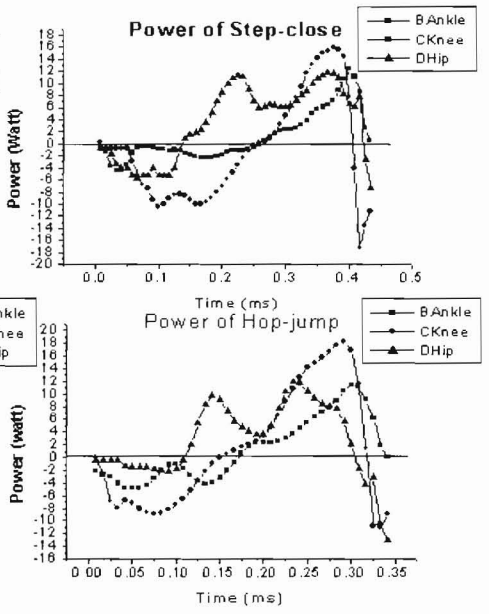

Figure 2. The power curve of one typical subject in hop and step-close jumps.

Figure 1 shows that ankle flexor, knee extensor, hip flexor are the dominating muscle groups during both jumpings. Figure 2 shows the dominated muscle groups contracted eccentrically to absorb the forward velocity during approaching landing, and then hip flexor contracted concentrically early before push-off. Table 2 shows the works of knee during eccentric contraction were greater than ankle and hip in both volleyball-spiking jump. The results were different from Devita and Skelly´s (1992) landing study, they indicated ankle planter flexors provide major energy absorption (44% of the total muscular work) during the landing. The difference may be due to the volleyball approaching landing for take-off using knee flexor for reducing the forward velocity the of body at landing. The works of knee and hip joints during

eccentric contraction are significantly greater in step-close jump than in hop-jump. Bobbert *et al.* (1996) indicated that the amount of energy stored in a series of elastic elements at the start of the concentric phase is not determined by the amount of "negative work" performed but by the force at the begining of push-off. In this study, hop jump has greater ankle and hip moment but a smaller knee moment than the step-close at the start of the push-off.

Table 2. Angle, moment and work in two volleyball jumps.

Variable	Hop-jump	Step-close	Effect size	Power
Angle at initial landing				
Ankle	127.5±4.6	131.4±5.7		
Knee	136.8±5.3	140.8±6.9		
Hip	107.4±7.3	104.6±3.5		
Angle at LPCOM				
Ankle	91.4±9.1	91.5±10.5		
Knee	96.4±8.5	93.6±9.3		
Hip	107.7±9.8	106.8±13.5		
Moment at start push-off (N m/kg)				
Ankle	2.26±0.5	1.85±0.6*	0.65	0.92
Knee	1.98±0.5	2.24±0.6*	0.54	0.81
Hip	2.21±0.4	1.85±0.4*	0.60	0.88
Work in eccentric contraction (J)				
Ankle	0.69±0.4	0.68±0.4		
Knee	0.90±0.2	1.50±0.5*	0.94	0.99
Hip	0.34±0.1	0.59±0.3*	0.43	0.70
Work in concentric contraction (J)				
Ankle	1.22±0.3	1.0±0.2*	0.65	0.94
Knee	0.90±0.4	1.08±0.4		
Hip	1.86±0.6	2.01±0.7		
Total work (%)				
Ankle	32±9	26±9*	0.69	0.93
Knee	30±10	36±10*	0.57	0.84
Hip	38±9	38±8		

Note. *Statistical significant difference between hop and step-close jumps.

This may explain why there was no difference between two jumps height. Table 2 also shows the percentage of total work contributed by ankle, knee and hip for hop and step-close jump. The hips have a greater contribution on both jumps. The similar study of results were reported by standing long jump with arms swing (Horita, Kitamura and Kohno, 1991). However, the study of vertical jump with the arms akimbo (Van Soest *et al.*, 1985) indicated that the knee has a greater work contribution during the jump take-off. The different results among those studies may be due to the different approach take-offs and with or without arms movement.

CONCLUSION: The purpose of this study was to investigate the net muscle moments and works on lower limbs in two different volleyball-spiking jumps by inverse dynamics. The results revealed that the works done in knee joint during eccentric contraction were greater than ankle and hip joints in the two volleyball jumps. In addition, the hip has a greater work contribution on both hop and step-close jump.

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