KINETIC EFFECT OF A FOUR-STEP AND STEP-CLOSE APPROACH IN A VOLLEYBALL SPIKE JUMP FOR FEMALE ATHLETES

ChengTu Hsieh, Sean M. Cascarina, and Justin B. Pingatore

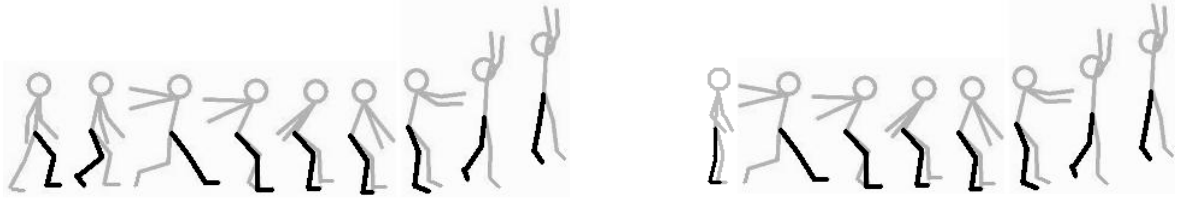
California State University, Chico, CA, USA

The purpose of the present study was to investigate the kinetic difference between two different volleyball spike jump techniques: a complete four-step approach and step-close approach. Five female collegiate volleyball players (age: 20.40 ± 1.85, height: 1.80 ± 0.02 m, body weight: 71.71 ± 4.18 kg) who play the middle hitter position were recruited. Each participant performed ten jumps for both four-step and step-close approaches and takeoff from two Kistler force platforms. Results indicated that there is no significant difference (P = .18) of vertical propulsive impulse between the two types of jump. The anterior-posterior (AP) net impulse of the four-step approach was significantly greater than a step-close approach (P < .01). Finally, the contact duration of propulsive phase for step-close technique is significantly greater than four-step approach technique (P < .05).

KEYWORDS: approach, impulse, kinetics, volleyball spike jump.

INTRODUCTION: The International Volleyball Federation (FIVB) defined attack hit as "*All actions which direct the ball towards the opponent, with the exception of service and block*" (FIVB, 2008). The volleyball attack hit is an important offensive tool which dominates the result of a competition. One type of the attack hit involves maximum jump height with approach. Jump height of the hit provides the advantage of attack angle and time in the air (Abendroth-Smith & Kras, 1999). The mechanism of jumping has been investigated from many different perspectives which incudes muscle mechanics and segmental kinematics and kinetics (i.e., Dapena & Chung, 1988; Moran & Wallace; Vint & Hinrichs, 1996; Wagner, Tilp, Duvillard, & Mueller, 2009). Kayambashi (1977) indicated that the number of approach steps resulted in different jump height for male volleyball players. Hsieh and Christiansen (under review) indicated that there is no significant relationship between approach velocity and jump height in women volleyball players. By comparing two different types of jump, step-close and hop jump, there was no significant difference at jump height or vertical impulse between the two styles (Coutts, 1982; Gutiẻrrez-Davila, Campos, & Navarro, 2009). However, the vertical impulse is enhanced as the last step length increases for male volleyball players (Liu, Huang, & Huang, 2001). Therefore, these studies showed that different approach techniques have different effects on jump height for men and women volleyball players.

In a regular volleyball match, the middle hitter has to play an active role by running a "quick" or "slide" in front of or behind the setter regardless if the setter is going to set the ball to him or her. In many situations, especially during a rally, the middle hitter has little or no time to pull back far enough to perform a complete three- or four-step approach after a block; instead, he/she has to take a step-close approach to jump (Figure 1). Thus far, no research has examined the kinetic comparisons between a four-step and step-close approach jump in female volleyball players. Therefore, the purpose of the present study was to investigate the



Four-step approach Step-close approach

Figure 1. Figures above show a complete four-step approach and step-close jump (Note: solid black line represents right lower extremities).

propulsive vertical and horizontal impulse (AP impulse) between a four-step and step-close approach jump in female volleyball players. Furthermore, the results may provide suggestions to the middle hitter for different techniques to improve jumping skills.

METHOD: A total of five female collegiate volleyball players (age: 19.40 ± 1.85, height: 1.80 ± 0.02 m, body weight: 71.71 ± 4.18 kg) were recruited. All policies and procedures for use of human subjects were followed and approved by the local Institutional Review Board. All participants had at least seven years of experience playing competitive volleyball and their current position on the court is middle hitter.

Each participant was requested to take five minutes of warm up with jogging and stretching before the data collection. After warm up, each subject was required to practice jumping on the two Kistler force platforms (Model 9286; 600 Hz) in order to mark the starting position for either a four-step approach spike jump or step-close approach spike jump. Kistler Bioware® software was used to analyze 5 seconds of force data. During the data collection, each participant was required to perform ten maximum volleyball spike jumps using four-step approach and another ten using step-close style to jump as high as possible. A trial was excluded when the subject's feet failed to make full contact with both force platforms during takeoff phase. Thirty seconds and two-minute breaks were provided between trials and after the last trial, respectively.

A standard t-test was performed to compare the difference of propulsive vertical and horizontal impulses between a complete and step-close approach spike jump. The time between takeoff and landing from the GRF data was used to estimate the takeoff velocity (v = t/2*g) and the vertical propulsive impulse was calculated with body mass (vertical propulsive impulse = m*v) (Liu et al., 2001). Horizontal impulse was determined by using formula: $\int_{T_{initial}}^{T_{End\ of\ Braking\ Phase}} (F_{AP\ GRF}) \times \Delta time$, where time was the duration of positive AP force (braking phase). The duration of contact was from the beginning of the first foot impact to takeoff. To control for both type I and II errors, Holm's correction formula was utilized to calculate new adjusted critical *P*-value = $\alpha/(n-i+1)$, where *n* is the total number of comparisons and *i* is the order of comparison (Knudson, 2009; Lundbrook, 1998). Each observed *P*-value was compared to new adjusted critical *P*-value according to the equation provided.

RESULTS: Results showed that there was no significant difference of propulsive vertical impulse between the two types of approach techniques (*P* = .183). The complete four-step approach had significant greater horizontal impulse with *P*-value less than .001. Finally, the time for the contact phase indicated that the four-step approach had significant shorter duration with *P*-value of .03. Figure 2 represents a sample force-time graphs of vertical and AP GRF for both types of approach technique. The beginning of the foot contact for both type of jumps were matched in order to show the difference.

Table 1. Vertical and horizontal impulse and contact duration for both approach techniques

Techniques	Vertical Impulse (J)	Horizontal Impulse (J) *	Duration (s) *
Four-step approach	226.60 ± 26.65	136.89 ± 25.38	0.38 ± .05
Step-close approach	217.57 ± 24.81	104.68 ± 33.69	0.45 ± .15

Note: * indicates significant difference with *P*-value less than new adjusted critical *P*-value.

DISCUSSION: This study examined the effect of a complete four-step and step-close approach in volleyball spike jump for female players. Kayambashi (1977) investigated national team volleyball players and found that the number of steps was not correlated to the jump height in female athletes which supports the finding of the present study that there is no significant difference (*P* = .183) of the propulsive vertical impulse between four-step and step-close approach jump for this group of female players. The other finding in this study

showed that the four-step approach had greater braking horizontal impulse than the step-close approach which also implies that a complete approach had greater horizontal momentum (velocity). Studies have found that horizontal velocity is a crucial variable toward jump height when male participants were recruited for this special type of jumping technique (Liu et al., 2001; Wagner et al., 2009). However, in the current study using a group of female volleyball players, the results seem to contradict that finding.

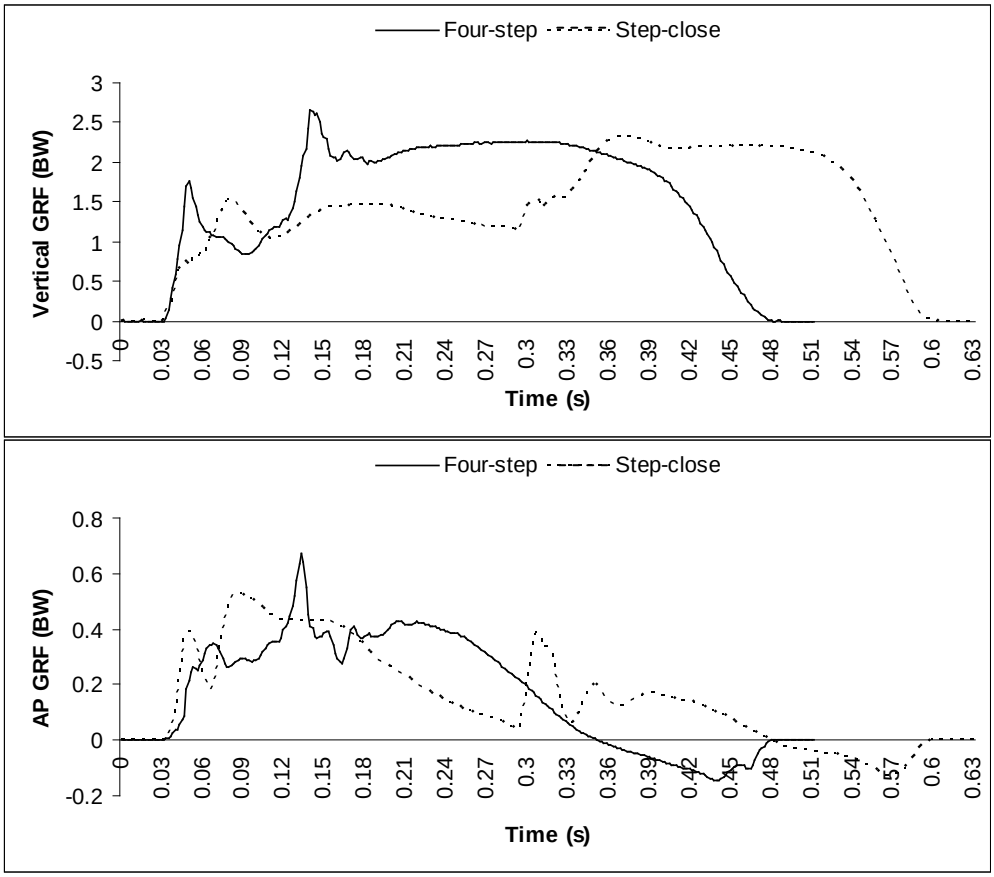


Figure . Sample vertical and AP GRF from one trial of a subject.

Results also showed that the four-step technique had significant shorter duration of contact phase which may result from greater horizontal momentum that speeds up the angular motion of the COM pivot over the supported legs to takeoff in a shorter amount of time. In addition, with greater horizontal momentum the completion of both feet impact was earlier than the step-close technique. On the other hand, the rate of vertical force development on the force-time graph was found to be slower in step-close technique due to the plant of both feet are further apart on timing when compare to four-step approach (Figure 2). This, coupled with the longer duration of contact phase, compromised the discrepancies of vertical impulse exertion at beginning of the contact phase for the step-close technique.

For a regular volleyball attack jump, studies have found that horizontal motion is minimized during the takeoff phase (i.e., Prsala, 1982). Additionally, Chen and Huang (2008) found that the back row attack had greater jump height when compared to front row attack for elite female volleyball players due to greater horizontal velocity at takeoff. This implies that when horizontal displacement is allowed after takeoff, the horizontal momentum from approach may have efficiently contributed to the jump height. Therefore, with significant different horizontal impulses, it may have represented different direction of the resultant GRF at beginning of the contact phase. This could explain how the transition of horizontal and vertical momentum was made. However, without further kinematic data such as the radial motion of the COM, it would be difficult to determine the mechanism of these two different approach techniques and how this group of athletes maintained similar results of vertical impulse. Another limitation includes a sampling frequency set at 600 Hz which may have

slightly underestimated the jump height by less than 1% (Street, McMillan, Board, Rasmussen, & Heneghan, 2001). Finally, all the subjects were required to perform the jumping techniques in the laboratory setting which may have influenced the jumping performance when compared to performing on the volleyball court, such as minimum horizontal displacement after takeoff.

CONCLUSIONS: The present study showed that step-close approach can create the similar amount of propulsive vertical impulse as the four-step approach spike jump which indicated the jump height is similar for both techniques. The AP impulse during braking phase showed that this group of performers had greater horizontal velocity due to the four-step approach technique. However, this horizontal momentum did not contribute to the vertical jump as other studies' findings when male subjects were recruited. Finally, the step-close technique has a longer period of contact phase which indicated that the average vertical force exertion may be different between the two techniques. Therefore, for this group of female volleyball players who play the middle block position may have a different jumping mechanism for both types of jumps to maintain similar performance results.

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