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A COMPARISON OF SINGLE- AND DOUBLE-LEG RUNNING VERTICAL JUMPS IN VOLLEYBALL

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Single- and double-leg vertical jumps are often performed in volleyball games. But the contribution from individual leg in single- and double-leg running vertical jump skills in volleyball has not been revealed. The purpose of this study was to determine the differences between single- and double- leg running vertical jumps (1-LRVJ and 2-LRVJ) on the biomechanical characteristics. Ten male college volleyball players voluntarily participated in this study. Two volleyball running vertical jumps were executed randomly. Three trials of each running vertical jump were recorded for each subject. Data were collected using six infra-red Qualisys motion capture cameras at 180 Hz sampling rate and two AMTI force platforms at 1800 Hz sampling rate, respectively. The jump height of 2-LRVJ was significantly higher than 1-LRVJ ($P < .05$), In push-off phase, 1-LRVJ had less angle change, but greater moment and higher impact force ($P < .05$). These results suggested that 1-LRVJ product higher leg stiffness with 2-LRVJ, it also increase higher risk of injury. We suggested using two- leg jumping style to enhance jump high, and avoid lower limbs injury.

KEY WORDS: kinematic, kinetic, biomechanics, running jump

INTRODUCTION: Single- and double-leg running vertical jumps are often performed in volleyball games. The running vertical jumps are stop-jumping activities involving a series of fast eccentric contraction following a concentric contraction on the lower extremity musculature which is so called stretch-shortening-cycle or SSC (Bobbert, Gerritsen, Litjens, & Van Soest, 1996). Cavagna (1977) suggested that bipedal animals use musculoskeletal springs to altemately store and restitute elastic energy during jumping. In the running jump transition, muscles, tendons, and ligaments collectively behave like a linear spring, store kinetic energy during approach run, and restitute it during the jump. Previous studies have shown the existence of a bilateral deficit in jump tasks (Liebermann & Katz, 2003). van Soest, Roebroeck, Bobbert, Huijing, & van Ingen Schenau, (1985) reported that human achieve less than twice the jump height of single-leg vertical jump during double-leg vertical jump.In addition, the information regarding biomechanical characteristics in the stop-jumping test at different running vertical jump skills is still limited. It is important to determine whether differences occur in single- and double-leg running vertical jump. Therefore, the purpose of this study was to determine the differences between single- and double-leg running vertical jumps on the biomechanical characteristics. Based on previous studies, we hypothesized that there would be differences found between single- and double-leg running vertical jumps.

METHODS: Ten elite male college volleyball players (age: 21.1 ± 2.2 years, weight: 80.7 ± 7.6 kg, height: 1.85 ± 0.04 m) voluntarily participated in this study. They were right-handed players. Two volleyball running vertical jumps, single- and double- leg running vertical jumps (1-LRVJ and 2-LRVJ), were executed randomly. The 1-LRVJ consisted of a left leg landing on a force platform and left leg takeoff. The 2-LRVJ consisted of a double-legged landing symmetrically with each leg on a separate force platform and a double-legged takeoff. The subjects were required to perform the vertical jump following a three-step approach running with great effort and to jump with arm swing as high as possible. Kinematic and kinetic data were collected using six infra-red Qualisys motion capture cameras (Oqus 100, Qualisys, Inc., Gothenburg, Sweden) at 180 Hz sampling rate and two AMTI force platforms (BP600900, AMTI, Inc., Watertown, MA, USA) at 1800 Hz sampling rate, respectively. The kinematic and kinetic data were filtered by a low-pass Butterworth digital filter at a cutoff frequency of 12 Hz (Bisseling and Hof, 2006; Ford, Myer, Smith, Byrnes, Dopirak, and Hewett, 2005).In this study, the landing phase was defined from ground contact to the lowest downward position, and push off phase was defined from the lowest downward position to take off. The statistical analyses were performed using SPSS 14.0 for Windows (SPSS, Inc., Chicago, IL, USA). Descriptive statistics (mean ± standard deviation, SD) were used to determine characteristics of subjects. The normality of continuous data was analyzed by the Kolmogorov-Smirnov test. A dependent student's t-test was performed for the biomechanical variables of the 1-LRVJ and 2-LRVJ The significance level was set at $\alpha = 0.05$.

RESULTS: Table 1 shows the means and standard deviations of each dependent kinematic variable of the lower extremities. The 1-LRVJ had a significantly smaller jump height than the 2-LRVJ ($p < 0.001$). There was a significant difference in the approach velocity between 1-LRVJ and 2-LRVJ ($p < 0.05$). The 2-LRVJ tended to produce a greater last step length than 1-LRVJ ($p < 0.001$).

Table 1
Means (standard deviations) of lower extremity kinematic variables of running vertical jump

	2-LRVJ	1-LRVJ	*P*-value
Jump Height (cm)*	53.7 (7.4)	34.5 (5.9)	＜0.001
Approach velocity (m/s)*	2.50 (0.22)	2.93 (0.56)	0.027
Last step length (m)*	1.40 (0.14)	1.08 (0.07)	＜0.001

Table 2 shows the means and standard deviations of lower extremity biomechanics variables during the landing of the 1-LRVJ and 2-LRVJ tasks. In this phase, there was no difference between two tasks at eccentric time. The angle value at the knee and hip joint of the 1-LRVJ was significantly less than the angle value at the knee joint in 2-LRVJ ($p < 0.05$). Eccentric impulse and ground reaction force at lower extremity of 1-LRVJ were significantly greater than 2-LRVJ ($p < 0.05$). The 1-LRVJ had significantly greater hip work during landing than the 2-LRVJ ($p < 0.05$).

Table 2
Means (standard deviations) of lower extremity biomechanics variables during the landing of the 1-LRVJ and 2-LRVJ

	2-LRVJ	1-LRVJ	*P*-value
Eccentric Time (s)	0.16 (0.02)	0.17 (0.02)	0.365
Ankle Flex Angle at Contact (°)	-4.63 (13.45)	-8.19 (7.86)	0.198
Knee Flex Angle at Contact (°)*	37.83 (11.36)	27.64 (5.79)	0.023
Hip Flex Angle at Contact (°)*	39.35 (6.91)	33.59 (7.49)	0.003
Eccentric Ankle Impulse (BWs /BH)*	1.21 (0.50)	1.55 (0.49)	0.020
Eccentric Knee Impulse (BW×s /BH)*	-3.33 (0.66)	-4.26 (0.60)	0.001
Eccentric Hip Impulse (BW×s /BH)*	1.44 (0.41)	2.49 (1.02)	0.002
Eccentric GRF Impulse (BW×s)*	37.69(4.42)	60.14 (4.37)	＜0.001
Eccentric Ankle Work (Watt/BW×BH)	-3.72 (1.68)	-3.28 (1.11)	0.206
Eccentric Knee Work (Watt/BW×BH)	-13.68 (3.90)	-13.00 (4.61)	0.710
Eccentric Hip Work (Watt/BW×BH)*	0.07 (0.92)	1.77 (2.38)	0.045

Table 3 shows the means and standard deviations of lower extremity biomechanics variables during the push off phase of the 1-LRVJ and 2-LRVJ. The concentric time at 1-LRVJ was shorter than 2-LRVJ, and the change of knee flexion angle was also less than 2-LRVJ. But peak ground reaction force was significantly greater than 2-LRVJ ($p < 0.001$). The 2-LRVJ produced a significantly greater peak ankle, knee, and hip flexion angle and moment during push off in comparison to the 1-LRVJ ($p < 0.001$). The 1-LRVJ produced a significantly greater concentric impulse at knee and ground reaction force during push off in comparison to the 2-LRVJ ($p < 0.05$). The negative value means the brake impulse and the positive value means the propulsive impulse.

Table 3
Means (standard deviations) of lower extremity kinetic variables during push off phase of the single- and 2-LRVJ tasks

	2-LRVJ	1-LRVJ	*P*-value
Concentric Time (s)*	0.16 (0.01)	0.14 (0.02)	0.043
Change of Knee Flex Angle (°)*	47.94 (10.56)	35.53 (5.74)	0.010
Peak GRF (BW)*	1.63 (0.19)	3.02 (0.38)	<0.001
Peak Ankle Flex Angle (°)*	11.12 (4.93)	-5.11 (4.44)	<0.001
Peak Knee Flex Angle (°)*	85.78 (6.97)	63.17 (4.80)	<0.001
Peak Hip Flex Angle (°)*	35.11 (5.83)	25.06 (5.58)	<0.001
Peak Ankle Moment (BW×BH)*	0.13 (0.01)	0.17 (0.02)	<0.001
Peak Knee Moment (BW×BH)*	0.19 (0.02)	0.29 (0.07)	<0.001
Peak Hip Moment (BW×BH)*	0.08 (0.02)	0.14 (0.03)	<0.001
Concentric Ankle Impulse (BW×s /BH)	2.52 (0.40)	2.77 (0.49)	0.083
Concentric Knee Impulse (BW×s /BH)*	-2.78 (0.44)	-3.41 (0.49)	0.002
Concentric Hip Impulse (BW×s /BH)*	0.55 (0.33)	-0.03 (0.58)	0.006
Concentric GRF Impulse (BW×s)*	36.34 (4.30)	46.80(6.22)	0.001
Concentric Ankle Work (Watt/BW×BH)	11.21 (1.60)	10.51 (2.09)	0.325
Concentric Knee Work (Watt/BW×BH)	13.96 (3.34)	14.84 (3.66)	0.302
Concentric Hip Work (Watt/BW×BH)*	0.87 (0.76)	-0.59 (1.81)	0.010

Table 4 shows the means and standard deviations of lower extremity stiffness of the 1-LRVJ and 2-LRVJ. Lower extremity stiffness of 1-LRVJ were significantly higher than 2-LRVJ.

Table 4
Means (standard deviations) of lower extremity stiffness of the 1-LRVJ and 2-LRVJ tasks

	2-LRVJ	1-LRVJ	*P*-value
Ankle Stiffness (BW×BH/rad)*	0.12 (0.03)	0.18 (0.06)	<0.001
Knee Stiffness (BW×BH/rad)*	-0.20 (0.02)	-0.43 (0.10)	<0.001
Hip Stiffness (BW×BH/rad)*	0.11 (0.03)	0.20 (0.03)	<0.001

DISCUSSION: The purpose of this study was to determine the differences between single and double-leg running vertical jumps on the biomechanical characteristics. The difference of these two tasks in lower extremity kinematics and kinetics noticed in this study were consistent with those in previous literatures. The decreased knee flexion angle of single-leg running vertical jump at the initial foot contact of the ground in this study was consistent with those reported by Chappell et al. (2002) and Decker et al. (2003). The combination of increased approach velocity of single-leg running vertical jump during landing and decreased knee flexion angle of single-leg running vertical jump at the initial foot contact of the ground was consistent with the characteristics of the landings with increased impact forces by Devita and Skelly (1992). At the initial foot contact of the ground, the higher approach run speed produced the higher impact force.

As our results show, the single-leg running vertical jump produced a greater vertical ground reaction force than the double-leg running vertical jump, which was likely due to the smaller lower extremity flexion angles at initial foot contact of the ground, and the smaller maximum hip and knee flexion angles during landing. The results obtained in the current study were consistent with those of previous studies examining the ground reaction forces and knee kinematics during single-leg and double-leg drop jump (Ruan & Lee, 2008).

Moreover, Bridgett & Linthoren (2006) indicated that the higher approach velocity may shorten the ground contact time and decrease the vertical impulse at concertric stage in running vertical jump. The results of this study show that the maximum ground reaction force and the peak moment at push off phase were significantly greater in single-leg running vertical jump compared to double-leg running vertical jump. The single-leg running vertical jump also produced great impulse during the landing phase which could be caused by the high velocity of approach run in the take-off phase and the great maximum ground reaction force. These aforementioned factors could also influence the jump hight difference between the single-leg and double-leg running vertical jumps.

Variations in the speed and stride length in the last step of the approach run are the main limitations of this study. Subjects were instructed to perform a three-step approach with great effort, however the approach speed was not restricted and the stride length was not adjusted. These parameters could affect the magnitudes of the evaluated joint reaction forces and moments. In addition, we only investigated the kinetic and kinematic of the landing of the running vertical jump task. It should be considered in future studies to understand the mechanism and risk factors of running-jump tasks.

CONCLUSION: In summary, there are significant differences of kinetics and kinematics between single- and double-leg running vertical jumps. Moreover, the jump performance in the single-leg running vertical jump may be affected by the following factors: 1) decreased hip and knee flexion angles at initial foot contact of the ground; 2) extention moment of the hip joint at initial foot contact of the ground; 3) decreased peak hip and knee flexion angles during the landing phase; 4) increased peak vertical ground reaction forces, impulse and stiffness.

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