INFLUENCE OF APPROACH SPEED AND DISTANCE ON BIOMECHANICS DURING SINGLE-LEGGED RUNNING VERTICAL JUMP

Wei- Hsun Tai[1], Shin-Liang Lo[2], Ching-Fang Yu,[2] Min-Hsien Wang[2], Chen-Yi SONG[3] and Hsien-Te Peng[2]

Graduate Institute of Sport Coaching Science, Chinese Culture University, Taipei, Taiwan[1]
Department of Physical Education, Chinese Culture University, Taipei, Taiwan[2]
Department of Health Promotion and Gerontological Care, Taipei College of Maritime Technology, Taipei, Taiwan[3]

The purpose of this study was to look into the kinematics, kinetics and EMG of the single-legged running vertical jumps in different approach speed and distance. 12 basketball player performed single-legged running vertical jumps with 2 approach speed and 3 distance randomly. Kinematic and kinetic data were collected by a force and 11 infrared high speed cameras. EMG data were recorded by Delsys surface EMG system. Two-way repeated measures ANOVA (2 speeds × 3 distance) was used for establishing differences (significance level p< .05). The jump height, joint moment of lower extremity, knee power and the activation of tibialis anterior and gastrocnemius were found significantly larger in fast approach speed. We suggested using fast approach speed and 9m approach distance to enhance the single-legged running vertical jump ability.

KEY WORDS: biomechanics, EMG, running jump

INTRODUCTION: Jumping performance is one of most important factors in basketball skills such as lay-up or slam dunk. And these movements are influenced by the power of lower extremity. It can be improved by using plyometric training for jumping performance, but there still is some special training movement similar to the lay-up that should be noticed such as the single-legged running vertical jump. The performance of the single-legged running vertical jump is determined by several factors including the maximal force generation capacity and stretch shortening cycle (SSC) used (Rimmer & Sleivert, 2000).
In practice, the single-legged running vertical jump is often used for training to enhance the jumping performance by cosches and athletes. But it is hard to for them to deside how much the approach speed and distances they need to increase the takeoff velocity of the single-legged running vertical jump, for the performance. Although previous researches indicated that the approach speed depends on athletes' lower limb power generation, the approach distance could be a way to control the approach speed to reach optmal takeoff velocity for best performance (Miura, Yamamoto, Tamaki, & Zushi, 2010).
Although previous studies has compared the kinematic, kinetic and EMG parameters between vertical jump, drop jump and running drop jump (Markovic, 2007; Leukel, Gollhofer, Keller, & Taube, 2008; Ruan & Li, 2010), the research of the single-legged running vertical jump is still limited. As far as we know, the jump performance or SSC function of muscle increased when the approach speed increased (Dapena, 1980; Ishikawa, & Komi, 2004; Ruan & Li, 2008, 2010). Increasing the approach speed is one of important factors for attaining greater jumping performance (Hay, 1993) and leading to large muscle forces (Alexander, 1990). However, how the approach distances would influence approach speed is unknow. It is worth to investigate the biomechanical characteristics in the single-legged running vertical jump with different approach speed and distance.
Therefore, the purpose of this study was to look into the kinematics, kinetics and EMG of the single-legged running vertical jumps such like lay-up in different approach speed and distance. We hypothesized that the single-legged running vertical jump with the increase of approach speed and distance would increase the performance, joint moment and power output, and muscle activation of the lower extremity.

METHODS: Twelve male collegiate Division III basketball players (age: 21.9 ± 1.3 years, weight: 75.1 ± 8.3 kg, height: 1.81 ± 0.07 m) voluntarily participated in this study. Participants performed the single-legged running vertical jump with 2 approach speeds (slow and fast) and 3 distances (3m, 6m and 9m) randomly. Each condition was performed 3 times.

The participants were required to perform the running vertical jump fallowing a custom-made LED lighting controller which was set a 4 m/s speed. They were instructed to do the single-legged running vertical jumping a little bit slower than the LED lighting controller for the slow approach speed and as faster as possible than the LED lighting controller for the fast approach speed with great effort. They were allowed to swing their arms to jump as high as possible to reach a target set on the ceiling with a height of their 100% standing vertical jump heights.

The kinematic and kinetic data were collected by a force platform (AMTI Inc., Watertown, MA, USA) set at 2000Hz sampling rate and 11 infrared high speed cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) set at 200Hz sampling rate. EMG data were recorded by Delsys surface EMG system (Delsys Inc., Boston, MA, USA) set at 2000Hz sampling rate. The force platform, cameras and EMG system were synchronized using EvaRT 4.6 (Motion Analysis Corporation, Santa Rosa, CA, USA).

Data were transformed and analyzed using the MotionMonitor software (Innovative Sports Training Inc, Chicago, Illinois, USA). Jumping height was calculated using center of mass (COM). Approach velocity at touchdown of the center of mass was calculated at the instant of foot touchdown. Joint moment and power were calculated using inverse dynamics in the MotionMonitor software. Surface electrodes were placed on the muscle belly of the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), gastrocnemius (GAS) and soleus (SOL) of the dominant leg after the subject's skin was cleaned. The EMG data were filtered by bandpass filter (20-450 Hz) and smoothed by root mean square (RMS) within a 50ms moving window. The EMG data were normalized by reference voluntary contraction (RVC) which was defined as maximum RMS during standing vertical jump and all data were shown as a percent of RVC (Lehman & McGill, 1999). All data were analyzed from foot touchdown to takeoff of the ground which was determined by assessing 20-Newton vertical ground reaction force threshold.

The statistical analyses were performed using SPSS 20.0 for Windows (IBM SPSS Statistics 20.0.0, Somers, New York, USA). Descriptive statistics (mean and standard deviation, M and SD) were used to determine characteristics of participants. Two-way (2 speeds × 3 distance) repeated measures ANOVA, complemented with Bonferroni *post hoc*, was used for establishing differences between conditions. The significance level was set $p < .05$.

RESULTS: We examined the interactions between approach speeds and distances before presenting the statistical effects. Only approach velocity at touchdown showed significant interaction ($F_{(2,22)} = 5.989$, $\eta^2 = .353$, Power = .832, $p = .008$).

Table 1 shows the means and standard deviations of variables for each approach speed. The jump height, peak hip, knee, and ankle joint moment, knee power, TA_{rms} and GAS_{rms} were significantly higher in fast approach speed than in slow approach speed.

Table 2 shows the means and standard deviations of approach velocity at touchdown in 2 approach speeds and 3 distances. In slow speed, the approach velocity at touchdown of 3m approach distance was significantly smaller than that of 6m and 9m. In fast speed, the approach velocity at touchdown of 3m and 6m was significantly smaller than that of 9m. In comparison between fast and slow approach speeds, the approach distance of 3m ($F_{(1,11)} = 1.814$, $\eta^2 = .778$, Power = .1, p =.000) and 9m ($F_{(1,11)} = 41.998$, $\eta^2 = .792$, Power = .1, p =.000) showed significant difference.

Table 1
Means and standard deviations of variables for each approach speed

	Slow		Fast					
	M	SD	M	SD	F	η^2	Power	p
Jump height (m) *	0.75	0.03	0.79	0.02	7.009	.389	.674	.023*
Peak hip moment (Nm) *	392.5	32.1	436.1	28.9	12.710	.536	.900	.004*
Peak knee moment (Nm) *	125.8	13.6	148.6	13.7	11.692	.515	.875	.006*
Peak ankle moment (Nm) *	241.6	11.0	261.7	18.0	6.192	.360	.621	.030*
Peak hip power (W/kg)	174.0	23.9	145.1	25.9	1.374	.111	.188	.266*
Peak knee power (W/kg) *	144.0	10.6	182.2	19.1	5.163	.319	.545	.044*
Peak ankle power (W/kg)	96.1	4.2	102.3	6.0	2.830	.205	.336	.121*
Knee range of motion (°)	63.0	4.1	57.9	5.7	2.528	.187	.306	.140*
RF_{rms} (%RVC)	96	11	104	17	0.732	.062	.123	.410*
BF_{rms} (%RVC)	131	30	168	54	0.533	.046	.103	.481*
TA_{rms} (%RVC) *	118	37	195	57	6.629	.376	.650	.026*
GAS_{rms} (%RVC) *	85	11	109	15	7.368	.401	.696	.020*
SOL_{rms} (%RVC)	138	37	147	26	0.119	.011	.062	.737*

Note. *M* = mean; *SD* = standard error of the mean; * significant difference found, $p < .05$.
Source and error degrees of freedom for all *F* tests were 1 and 11, respectively.

Table 2
Means and standard deviations of approach velocity at touchdown in 2 approach speeds and 3 distances.

	3m		6m		9m						
	M	SD	M	SD	M	SD	F	η^2	Power	p	Homogenous
Slow speed (m/s)	3.53	0.42	4.11	0.50	4.06	0.55	14.014	.560	.996	.000	3m < 6m, 9m
Fast speed (m/s)	4.07^a	0.37	4.33	0.44	4.64^b	0.42	15.426	.584	.998	.000	3m, 6m < 9m

Note. * significant difference found, [a] fast speed > slow speed in 3m approach distance, [b] fast speed > slow speed in 9m approach distance, $p < .05$; 3m = approach distance of 3m; 6m = approach distance of 6m; 9m = approach distance of 9m; *M* = mean; *SD* = standard error of the mean; source and error degrees of freedom for all *F* tests were 2 and 22, respectively.

DISCUSSION: In the current study, the performance of the single-legged running vertical jump was consistent with those reported by Dapena (1980) and Ruan & Li (2008). The most significant influential factor of the approach was observed in the slow and fast approach speed. The lower extremity joint moment and knee power were increased in the fast approach condition. It still should be noted that the approach velocity at touchdown produced in the slow speed with 9m approach distance was even closed to that in the fast speed with 3m approach distance. Moreover, these results supported our hypotheses that joint moment and power of lower extremity increased when the approach speed increased.

An intersting finding was that participants increased their approach speed in 9m approach distance but no significant increase of jumping performance was found. Meanwhile, participants seemed not be able to increase the approach speed in 3m approach distance compared to 6m and 9m approach distance. We suggested that there might be an optmal approach speed and distance for the best single-legged running vertical jumping performance. Further studies would be needed to be guaranteed to this perspective.

As the results showed, the muscular activation of tibialis anterior and gastrocnemius were larger when the approach speed was fast. Although there were no significant increases found in rectus femoris and biceps femoris, but there still some increases in %RVC of these muscles. It could affect hip and knee joint moment. And a possible explanation for larger leg muscle activity may be due to the muscle preactivation (Ruan & Li, 2010). Fast approach speed could induce greater muscle preactivation compared to slow approach speed. The greater activation of tibialis anterior and gastrocnemius in fast approach speed could provide more effective braking force and result in a good jumping performance (Kyröläinen and Komi,1995). Furthermore, the fast approach speed may induce not only the activation of tibialis anterior and gastrocnemius muscles but also the stretch reflex of the muscles (Bobbert & van Ingen Schenau, 1988).

CONCLUSION: In summary, a single-legged running vertical jump with faster approach speed produced greater joints moment output and better jumping performance. The greater joints moment output may be due to the greater tibialis anterior and gastrocnemius muscle activation associated with the braking movement. Moreover, 9m approach distance allowed participants to reach the fastest approach speed. We suggest that single-legged running vertical jump can use as a training method.

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