

Original Article

The role of biomechanical parameters and muscle activity during eccentric and concentric contractions in vertical jump performance

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Abstract:

The purpose of the present study was to investigate the effects and relationships between Biomechanical parameters and muscle activity during the eccentric and concentric contractions on height of vertical jump, and determined the role of every phase (Eccentric and Concentric contractions) to enhance the vertical jump performance. Five male high level athletes participated in this study were volleyball players (age: 20.4 ± 0.894 years; body mass: 83.38 ± 8.72 kg; height: 189.4 ± 9.04 cm). The vertical jumps were performed on a two-dimensional analysis, strain gage force platform, and EMG signals were recorded and amplified by ME6000 telemetric hardware system. Results showed in eccentric contraction phase the average angle of the knee at amortization in countermovement jump arm swing (105.19 ± 10.44), countermovement jump no arm (93.90 ± 6.68), and the more of muscle activity at this phase was Tibialis anterior in eccentric contractions phase, and the eccentric contraction phase is an important phase if they are used correctly as they lead to an improvement in the jump height by more than 8%. As well as in concentric contraction phase and the important parameter in the concentric contraction phase is time of maximum force to takeoff instant. Finally a great importance of muscles (Biceps femoris, Rectus femoris and Tibialis anterior), because they work to balance between the agonist muscles and antagonist muscles during the eccentric contraction phase and concentric contraction phase in vertical jump performance.

Key words: Biomechanics, stretch–shortening cycle, jumping, Electromyography, force platform..

Introduction

Many studies investigated the performance of vertical jump in its different types, especially from the biomechanical performance considering that the performance of the vertical jump is subject to the laws of projectiles because the body loses contact with the ground and moves to the upward of reverse gravity, and based on the force gained by the result of the ground reaction force and how to take advantage of all the natural factors (physical laws) and physical abilities and skills to be determined vertical jump height and which reflects a player's ability to perform the highest high and then achieve many of the objectives and results in skills and various sports activities.

The vertical jump is very important in sports. A high vertical jump contributes to successful athletic performance, particularly in sports such as basketball, volleyball, and football (Bobbert and van Ingen Schenau, 1988; Pandy and Zajac, 1991; Van Soest et al., 1993). And hopping, jumping, and running are considered as most typical forms of SSC (Komi and Nicol, 2011). In many sporting movements, the muscles contract in a stretch–shortening cycle (SSC) sequence, whereby the concentric contraction phase is immediately preceded by an eccentric contraction phase (active pre-stretch) (Ettema et al., 1990). Countermovement jumps (CMJ) are also SSC actions, because they include the sequence of stretch and shortening (Komi and Nicol, 2011). The combination of eccentric and concentric actions forms a natural type of muscle function called the stretch-shortening cycle or SSC (Norman and Komi, 1979; Komi, 1984; Komi and Nicol, 2000; Komi, 2000).

Studies of the neuromuscular system often employ recordings of the electrical activity of skeletal muscle. These electromyographic recordings may be of electrical signals detected within a muscle via needle or wire electrodes or from the surface of the skin via surface electrodes. Surface electromyography (EMG) is frequently used to estimate the amount of muscle activation required for specific tasks (Soderberg and Cook, 1983; Veiersted et al., 1990), and to examine changes in muscle activation as a result of training (Narici et al., 1989). Despite the fact that performance improvement is attributed mainly to neural factors, few researchers evaluated simultaneously the changes in performance with the changes in muscle activation using surface

electromyography (EMG) (Jones and Lees, 2003). Generally the EMG signal variables related to the amplitude of the electrical activity (root mean square, i.e. RMS or integrated EMG, i.e. IEMG) is quantified as activity level (Özgünen et al., 2010).

In a vertical jump, there are two ways to propel the body's center of mass (CM) upward: a countermovement jump (CMJ) and a so-called squat jump (SJ). In a CMJ, people start from an upright position and initiate downward movement before starting to move upward, while in a SJ they start from a squatted (or semi squatted) position without a preparatory countermovement. It is well known that CMJ are generally 2- 4 cm higher than SJs as a result of the stored elastic energy (Komi and Bosco, 1978), stretch reflexes (Viitasalo and Bosco, 1982), and the active states of the muscles (Bobbert and Casius, 2005).

The time history of the vertical ground reaction force (GRF) of a CMJ decreases below body weight during eccentric contraction phase in the counter movement and rises to a few times body weight in the concentric contraction phase (Fukashiro and Komi, 1987; Hubley and Wells, 1983; Vanezis and Lees, 2005).

And some views indicate that it may be beneficial to increase the range of motion of the stretching phase and decrease the range of motion of the shortening phase, in many complex movements this is not possible as an increase in the joint range of stretching tends to result in an increase in the range of shortening (Moran and Wallace, 2007), they depend to the previous studies results, (1) the magnitude of enhancement in mechanical output of the concentric contraction phase is greater with an increase in eccentric loading (Bober et al., 1987; Cavagna et al., 1968); (2) the magnitude of enhancement in mechanical output of the concentric contraction phase is greater with an increase in the range of stretch, provided the range of shortening is fixed (Ettema et al., 1990); but (3) the magnitude of enhancement in mechanical output of the concentric contraction phase decreases with an increase in the range of shortening (Bober et al., 1987; Chapman et al., 1985). And the result of study showed this enhancement is significantly increased with a smaller range of motion that is from a knee joint angle of 70° at the start of the propulsive phase compared to a knee joint angle of 90°. The enhancements from 70° of knee flexion were due to significant increases in work done at all three joints; while from 90° of knee flexion, only the hip and ankle joints appeared to contribute (Moran and Wallace, 2007). While the peak knee flexion ranges for optimal jump heights were shown to be between 100° to 130°, then after 130° jump height decreased (Clansey and Lees, 2010). It is not only necessary to examine the relationship between SSC functioning and range on motion but should to increase our understanding about the role of eccentric and concentric contractions in vertical jump from all sides (Biomechanical parameters and muscle activity).

The purpose of the present study was to investigate the effects and relationships between Biomechanical parameters and muscle activity during the eccentric and concentric contractions on height of vertical jump, and determined the role of every phase (Eccentric and Concentric) to enhance the vertical jump performance.

Method

Participants

Five male high level athletes participated in this study were volleyball players (age: 20.4 ± 0.894 years; body mass: 83.38 ± 8.72 kg; height: 189.4 ± 9.04 cm). They were athletes in the state of Alexandria, Egypt, and participated in regional and national competitions; and they are members of a professional team that plays in the Egyptian Volleyball Super League.

Measures

To perform CMJ arm swing, the athlete started at a static standing position with hands are free, and the jump was preceded by a countermovement of acceleration below the center of gravity achieved by flexing their knees to about 90 degrees, an angle that was observed and visually controlled by the examiner. During the jump, the trunk was kept as vertical as possible, and the athlete was instructed to jump at the highest possible speed and to the highest point that they could reach. In this protocol, the agonist muscles were stretched during descent, when the elastic structures were stretched, and there was an accumulation of elastic energy that could be used when going up (concentric contraction phase). In CMJ no arm swing, the athlete did the same previous performance but started at a static standing position with kept hands on the hip. In SJ no arm swing, the athlete started the jump from a static position, with the knees at an angle of about 90 degrees, the trunk as vertical as possible, and the hands on the waist. The jump was performed without any countermovement, and there was only the concentric action of the agonist muscles involved in the movement. Before data collection, the athletes stretched and warmed up for a short time and then received technical instructions and trained specifically for CMJ to ensure that the protocol was standardized. This stage included about 5-6 CMJ arm swing, CMJ no arm swing and SJ no arm at intervals of about 1 min, and the number of jumps depended on the movement technique that each individual presented. After that, the athletes performed three CMJ arm swing, after a 2 min recovery interval performed the CMJ no arm swing, and after a 2 min recovery interval performed the SJ no arm swing.

Procedures

The vertical jumps were performed on a two-dimensional analysis, marker position data were obtained by a high-speed motion capture system (Fastec in Line Network-Ready High-Speed Camera, MaxTRAQ Motion Analysis System to capture) at a frequency of 250 Hz, video point v 2.5 2D motion analysis for kinematic

parameters. In addition, strain gage force platform (MP4060®, Bertec Corporation, Columbus, OH, USA), which measured the vertical component of ground reaction force (GRF) at a sampling rate of 1000 Hz. The biomechanical parameters were used in the eccentric contraction phase: Eccentric Duration (Tecc), Hip angle at amortization ($\Theta_{hip-ecc}$), Knee angle at amortization ($\Theta_{knee-ecc}$), Ankle angle at amortization ($\Theta_{ankle-ecc}$), Eccentric Negative peak Force (Fecc), Eccentric Impulse (Iecc) and Eccentric Work (Wecc). The biomechanical parameters were used in the concentric contraction phase: Concentric Duration (Tcon), Concentric Duration from initial to Positive peak Force (Ti-Fcon), Concentric Duration from Positive peak Force to takeoff (TFcon-TO), Concentric Positive peak force (Fcon), Concentric Impulse (Icon), Concentric Work (Wcon), Vertical Velocity at Takeoff (VyTO) and Flight Height (FH). Duration of (eccentric and concentric) were determined from the GRF-time curves, the impulse of (eccentric and concentric) were determined by the integration between force with time (the impulse is the area under the force–time curve), and work of (eccentric and concentric) were determined by the integration between force with displacement (the work is the area under the force–displacement curve). The integration was calculated by OriginPro 8.5 SR1 Data Analysis and Graphing Software. Bipolar, Ag/AgCl surface electrodes (SKINTACT, FS-521), Innsbruck, Austria) were placed on Gluteus Maximus (GM), Biceps femoris (BF), Rectus femoris (RF), Vastus lateralis (VL), Vastus medialis (VM), Gastrocnemius lateralis (GasL), Soleus (Sol), Tibialis anterior (TA), in eccentric contraction phase (muscle Symbol-ecc) and concentric contraction phase (muscle Symbol-con). The center-to center distance of the electrodes was 20 mm. Prior to mounting the electrodes the skin was shaved, abraded with sandpaper, and cleaned with alcohol. EMG signals were recorded and amplified by ME6000 telemetric hardware system (Mega Electronics Ltd., FINLAND) synchronized with the force platform and the motion capture system. Signals were digitized at 1000 Hz with the MEGAWIN version 3.1-b12 software. EMG full-wave rectification by RMS Averaging. Averaged RMS value is calculated according to the following equation:

$$RMSvalue [I] = \sqrt{\frac{\sum_{i=n}^{n+N-1} |Data_{RMS}[i]|^2}{N}}$$

Where: I = index of RMS data

i = index of raw data

N = number of data points in RMS calculation

n = [1, N+1, 2N+1, ...]. (Mega Electronics Ltd, 2008)

Statistical analysis

For the statistical analysis of the data the IBM SPSS Statistics 21 was used. Descriptive statistics, Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check data normality, and results showed that all parameters had a normal distribution. After that, the Student T-test for independent samples was used to compare results for eccentric contraction phase in CMJ arm swing and CMJ no arm swing, analysis of variance (ANOVA) was used to compare results for Concentric contraction phase in CMJ arm swing, CMJ no arm swing and SJ no arm, and the Pearson correlation to evaluate the relationships.

Results

Table 1 shows the most important parameters in eccentric contraction phase, that the time of eccentric contraction phase was as follows CMJ arm swing (0.81 ± 0.17), CMJ no arm (0.61 ± 0.09), and also the average angle of the knee at amortization in CMJ arm swing (105.19 ± 10.44), CMJ no arm (93.90 ± 6.68). While the impulse (Iecc) in CMJ arm swing (-38.39 ± 18.83), CMJ no arm (-38.31 ± 26.75) as well as the work (Wecc) in CMJ arm swing (11.34 ± 7.69), CMJ no arm (13.15 ± 17.12) while the differences were significant at 0.01 between the performance of CMJ arm swing and CMJ no arm in the parameters T ecc and $\Theta_{knee-ecc}$ while the parameters $\Theta_{hip-ecc}$, $\Theta_{ankle-ecc}$ differences were significant at the 0.05 level.

Table 1: Biomechanical Parameters & RMS activity of muscles (mean $\pm$ SD), (t-test) during Eccentric contraction phase measured in CMJ arm swing and CMJ no arm Performance.

Biomechanical Parameters & Muscles	CMJ arm swing		CMJ no arm swing		T-test	Sig
	Mean	S.D	Mean	S.D		
Tecc (s)	0.81	0.17	0.61	0.09	4.04	0.01
$\Theta_{hip-ecc}$ (°)	65.32	8.44	54.96	17.40	2.07	0.05
$\Theta_{knee-ecc}$ (°)	105.19	10.44	93.90	6.68	3.53	0.01
$\Theta_{ankle-ecc}$ (°)	80.26	5.87	76.19	4.24	2.17	0.04

Fecc (N)	-422.83	96.13	-413.53	149.32	-0.20	NS
Iecc (N.s)	-38.39	18.83	-38.31	26.75	-0.01	NS
Wecc (J)	11.34	7.69	13.15	17.12	-0.37	NS
GM-ecc (μv)	33.20	11.23	31.87	11.49	0.32	NS
BF-ecc (μv)	55.80	12.14	46.50	19.45	1.57	NS
RF-ecc (μv)	91.80	62.54	116.37	71.87	-1.00	NS
VL-ecc(μv)	115.43	45.43	143.63	42.49	-1.76	NS
VM-ecc (μv)	113.87	71.10	147.27	80.29	-1.21	NS
GasL-ecc (μv)	57.60	28.55	42.83	15.76	1.75	NS
Sol-ecc (μv)	50.67	17.01	70.03	33.09	-2.02	NS
TA-ecc (μv)	256.87	117.05	234.07	113.45	0.54	NS

NS=Non-significant

And shows values of muscles activity during the eccentric contraction phase and the more muscle activity at this phase was (TA-ecc) followed by muscles (RF-ecc, VL-ecc, VM-ecc) and there were no significant differences in muscles activity between performance CMJ arm swing and CMJ no arm in eccentric contraction phase.

Table 2:

Biomechanical Parameters & RMS activity of muscles (mean $\pm$ SD), (ANOVA) during concentric contraction phase and flight height measured among CMJ arm swing, CMJ no arm swing and SJ no arm swing Performance.

Biomechanical Parameters & Muscles	CMJ arm swing		CMJ no arm swing		SJ no arm swing		F	sig
	Mean	S.D	Mean	S.D	Mean	S.D		
Tcon (s)	0.38	0.04	0.38	0.04	0.36	0.06	0.62	NS
Ti-Fcon (s)	0.28	0.05	0.18	0.12	0.22	0.09	4.64	0.02
TFcon-TO (s)	0.10	0.01	0.20	0.10	0.14	0.04	8.56	0.00
Fcon (N)	1236.60	83.87	967.80	89.24	1168.87	208.71	15.02	0.00
Icon (N.s)	255.97	20.48	232.85	14.01	228.17	27.61	7.24	0.00
Wcon (J)	395.75	48.12	327.60	32.24	313.57	54.22	13.81	0.00
VyTO (m/s)	3.08	0.24	2.82	0.21	2.74	0.19	10.82	0.00
FH (m)	0.49	0.08	0.41	0.06	0.38	0.05	10.83	0.00
GM-con (μv)	214.13	69.75	208.93	66.56	192.60	54.57	0.46	NS
BF- con (μv)	232.93	56.63	192.10	68.47	152.33	61.93	6.23	0.00
RF- con (μv)	401.13	92.67	472.10	159.51	534.40	153.16	3.48	0.04
VL- con (μv)	531.60	216.99	541.30	164.67	579.33	160.77	0.29	NS
VM- con (μv)	439.93	86.83	505.13	100.94	470.13	109.95	1.61	NS
GasL- con (μv)	421.27	169.29	418.37	168.67	399.13	155.40	0.08	NS
Sol- con (μv)	347.33	92.57	342.23	80.21	359.53	82.11	0.16	NS
TA- con (μv)	292.77	101.76	215.21	100.77	153.93	81.54	8.04	0.00

NS=Non-significant.

And tables (2, 3) show Statistical descriptive and significant differences in the Biomechanical parameters among types of jump (CMJ arm swing, CMJ no arm and SJ no arm) during the concentric contraction phase and it was the most important results of this phase differences in parameter Ti-Fcon (CMJ arm swing 0.28 ± 0.05 , CMJ no arm 0.18 ± 0.12 and SJ no arm 0.22 ± 0.09). And it has a positive correlation with jump height (FH) at the 0.01 level (Correlation is significant at the 0.01 level (0.451). And differences in the parameter TFcon-TO, which appeared negative correlation with jump height (FH) at 0.01 (Correlation is significant at the 0.01 level (-0.453).

As well as differences in the parameters (Icon, Wcon, VyTO), where the relationships were positive (Correlation is significant at the 0.01 level) with jump height (FH) (Icon (0.521), Wcon (0.862), VyTO (0.999)). The tables also showed that the differences in the high jump as follows (CMJ arm swing > CMJ no arm > SJ no arm).

Table 3: The significant differences between means with using L.S.D for the Biomechanical Parameters & RMS activity of muscles during concentric contraction phase and flight height measured among CMJ arm swing, CMJ no arm swing and SJ no arm swing Performance.

Biomechanical Parameters & Muscles	Performance	Mean Difference		
		CMJ with arm	CMJ no arm	SJ no arm
Ti-Fcon (s)	CMJ with arm		.09767*	0.06
	CMJ no arm			-0.04
	SJ no arm			
TFcon-TO (s)	CMJ with arm		-.09527-*	-0.04
	CMJ no arm			.053*
	SJ no arm			
Fcon (N)	CMJ with arm		268.80*	67.73
	CMJ no arm			-201.07-*
	SJ no arm			
Icon (N.s)	CMJ with arm		23.11837*	27.7983*
	CMJ no arm			4.68
	SJ no arm			
Wcon (J)	CMJ with arm		68.14360*	82.172*
	CMJ no arm			14.03
	SJ no arm			
VyTO (m/s)	CMJ with arm		.26800*	.34733*
	CMJ no arm			0.08
	SJ no arm			
FH (m)	CMJ with arm		.08123*	.10415*
	CMJ no arm			0.02
	SJ no arm			
BF-con (μv)	CMJ with arm		40.83	80.60*
	CMJ no arm			39.77
	SJ no arm			
RF-con (μv)	CMJ with arm		-70.97	-133.267-*
	CMJ no arm			-62.30
	SJ no arm			
TA-con (μv)	CMJ with arm		77.55238*	138.833*
	CMJ no arm			61.28
	SJ no arm			

*. The mean difference is significant at the 0.05 level.

And show statistical descriptive and differences between the values of muscle activity during the concentric contraction phase of the three types of vertical jump and was the most active muscles (RF- con: CMJ arm swing 401.13 ± 92.67 , CMJ no arm 472.10 ± 159.51 and SJ no arm 534.40 ± 153.16 , VL- con: CMJ arm swing 531.60 ± 216.99 , CMJ no arm 541.30 ± 164.67 and SJ no arm 579.33 ± 160.77 , VM- con: CMJ arm swing 439.93 ± 86.83 , CMJ no arm 505.13 ± 100.94 and SJ no arm 470.13 ± 109.95 , GasL- con: CMJ arm swing 421.27 ± 169.29 , CMJ no arm 418.37 ± 168.67 and SJ no arm 399.13 ± 155.40 , Sol- con: CMJ arm swing 347.33 ± 92.57 , CMJ no arm 342.23 ± 80.21 and SJ no arm 359.53 ± 82.11), while differences appeared in only three muscles BF- con (CMJ arm swing > SJ no arm; $p < 0.001$), RF- con (CMJ arm swing < SJ no arm; $p < 0.04$), TA- con (CMJ arm swing > SJ no arm; $p < 0.001$) (see tables 2,3).

Discussion

Many studies have focused on research and analysis of the performance of biomechanical vertical jump, and the foundations and principles that will achieve the highest height and take advantage of the physical abilities and technique, but in this study was split the vertical jump performance into three phases: 1 – downward phase (eccentric contraction phase), 2 – upward phase (concentric contraction phase), 3 - flight phase, and because the most important are the first and second phases for the biomechanical and muscular

considerations as it phases of energy production and exert power and that will affect later on jump height, so when a muscle is eccentrically loaded (i.e., stretched) and immediately followed by a concentric action, energy will be produce (Król and Mynarski, 2012). it means that the first phase (eccentric contraction phase) and the second (concentric contraction phase) the jump height will be determined as a result of them, so they show the importance and the role of biomechanical parameters and muscle activity of the lower limb muscles and the relationships between these parameters on vertical jump height.

During the eccentric contraction phase reduced body down and because the muscle contraction is eccentric so active muscle is the flexor muscles of the ankle (Tabialis anterior muscle) which shows the activity of the muscle (TA-ecc) through (eccentric contraction phase) Table 1, with the activity less in muscle group that working to extension of the knee joint (RF-ecc-VL-ecc-VM-ecc) and because the contraction was eccentric and in the direction of gravity does not need to hyperactivity, except at the end of the phase until the amortization and the beginning the concentric contraction phase, and appeared during this phase the importance angle knee at instant of amortization where it was a strong positive correlation at level 0.01 with the flight height (0.482) and due to the importance of the knee angle when countermovement jump (Moran and Wallace, 2007), because there are limits to this angle so as not to increase not help the player to take advantage of the eccentric contraction phase, and not decreases the body more until not get a greater moments around the joints and increases resistance to gravity which affects the performance, so some studies showed that the optimum of knee angle ranging between 100° - 130° (Clansey and Lees, 2010).

When the player is downward to amortization the concentric contraction phase begins, it is the phase in which they are using all the abilities available to the player and what he acquired from eccentric contraction phase to achieve a higher height, and in the concentric contraction phase increases the energy and the movement of each segment of the body and be the extension muscles of the knee joint and ankle are the most active (RF-VL-VM-GasL-Sol), according to (Pupo et al., 2012 and Ugrinowitsch et al., 2007) the important mechanism in this type of eccentric-concentric movement is the stretch-shortening cycle. In this cycle, the elastic structures of the agonist muscles are stretched during descent in CMJ, and there is an accumulation of elastic energy that may be used when going up (concentric contraction phase) which contributes to the vertical jump performance. In addition the extension muscle of thigh (BF), and the results showed that there are significant differences in the three muscles are (BF-RF-TA), and the suggests the differences in muscle(RF) that this muscle is working to extend the knee joint and be active muscle through concentric contraction phase and because the performance of SJ no arm performance is a concentric contraction phase only so this muscle was in activity before the start of performance, due to the starting position in the performance of SJ no arm (see tables 2,3), because in small range of motions because the time and space is limited for joint flexion the contractile elements of the muscles have limited capacity to lengthen. It can result in considerably higher positive activity in muscles than that in jumps without countermovement (Kopper et al., 2013).

And also the differences in the muscles (BF-TA), which is (BF) of the flexor muscles of the knee joint and (TA) of the flexor muscles of the ankle, and is what leads to the biggest activity as a result of the transition from eccentric contraction phase to concentric contraction phase.

The results suggests to some of the important parameters for this phase, the most important parameter in this phase is the time of maximum force to takeoff, when the player achieves the maximum force it stops to take advantage of this force on the time from the maximum force instant to takeoff, so as not to lose this force. and the results showed that the maximum force in CMJ arm swing > CMJ no arm; 27.77%, while the time from the maximum force instant to takeoff the CMJ no arm > CMJ arm swing; 50%) resulting in a loss of force gained and also not to take advantage of all the energy the body where it led to a reduction in velocity at takeoff where she was in favor of CMJ arm swing by 9.22%, and confirms this the negative correlation between the time of maximum force to takeoff (TFcon-TO) with velocity at takeoff (-0.459 at 0.01), and the decrease of this time led to an increase in velocity and then increase in flight height because the relationship between flight height with velocity at takeoff in accordance with the projectile laws, and also a positive relationship between flight height and velocity at takeoff, so the velocity is a determinant of CMJ height (Pupo et al., 2012). The results showed also the increase of this time in the performance of CMJ no arm led to decrease of flight height compared to CMJ arm swing by 19.51%. While the studies indicated that the arm swing lead to enhancement in the vertical jump by between 6-10% (Lees et al., 2004). But when we compared the same parameter (TFcon-TO) between CMJ no arm and SJ no arm, we found this time in SJ no arm lower by 42.86%, as well as maximum force was greater by 17.2%, and though the final result of flight height for CMJ no arm by 7.89%, and is due to benefits achieved during the eccentric contraction phase of storing energy and benefit from them in concentric contraction phase led to compensate for this shortcoming, as well as the enhancement in the impulse by 2.05%, and also the work done during this phase increased by 4.47% in favor of CMJ no arm which indicates that the eccentric contraction phase contribute to increase the height by more than 7.89% if the player used his abilities correctly.

Conclusions

The eccentric contraction phase is an important phase if they are used correctly as they lead to an improvement in the jump height by more than 8%, and the important parameter in the concentric contraction

phase is time of maximum force to takeoff instant, must therefore performance concentric contraction phase at maximum velocity to take advantage of the force produced to increase work, impulse and the velocity at takeoff because their strong positive relationships with jump height. In the performance of SJ no arm player can achieve high jump by produces maximum force and in less time to increase the velocity and impulse at takeoff. A great importance of muscles (BF-RF-TA) because they work to balance between the agonist muscles and antagonist muscles during the eccentric contraction phase and concentric contraction phase in vertical jump performance.

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