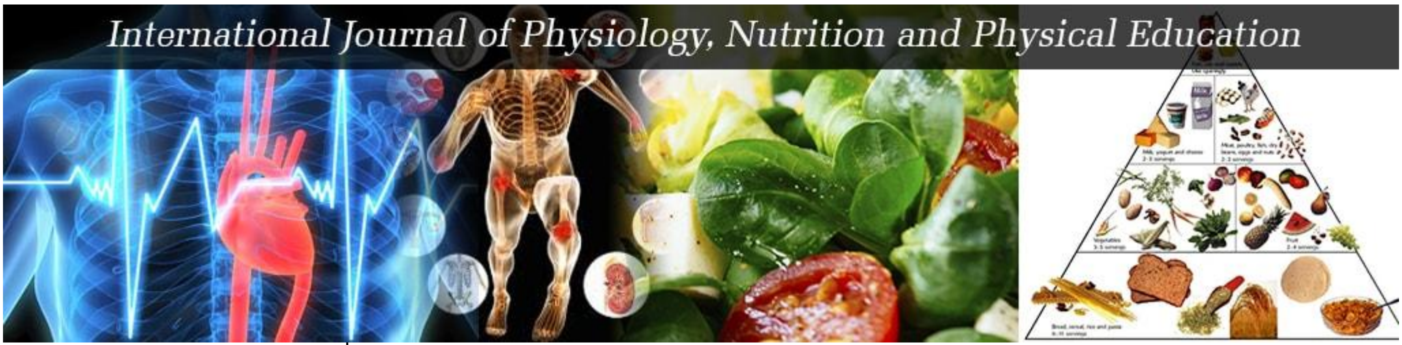

ISSN: 2456-0057
IJPNPE 2018; 3(1): 2043-2046

www.journalofsports.com
Received: 11-11-2017
Accepted: 12-12-2017

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Which isokinetic knee extensor strength affects vertical jump performance in Volleyball: Concentric or eccentric strength?

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Abstract
Vertical jump is one of the key determinants of success in explosive events like volleyball. A great amount of vertical jump is required to attack and block in the game of volleyball. Isokinetic knee extensor strength has been reported to be highly related to vertical jump. In the present study, two different modes of isokinetic knee strength (concentric and eccentric) were investigated for their relationship with vertical jump performance in sergeant jump test. A total of 18 U-20 volleyball players (Age 18.05±0.72yrs; Height 192.17±5.83cm and Body Weight 77.64±7.29 kg) from Indian U-20 national squad were employed for the purpose of the study. They were tested in laboratory at 60^0/s, 90^0/s and 120^0/s angular velocity using the Cybex isokinetic dynamometer (Humac Norm). The vertical jump performance was measured as difference between maximum standing height (with full arm reach overhead) and maximum vertical jump (VJ=62.81±5.33cm). A significant moderate correlation was observed between concentric knee extensor strength at 120^0/s angular velocities for dominant ($r= 0.582$; $p<0.05$) and non-dominant legs ($r= 0.519$; $p<0.05$) while eccentric knee strength was not related to jump height at all angular velocities. Although only 120^0/s angular velocity was significantly related to jump height, concentric knee strength at remaining angular velocities (60^0/s and 90^0/s) was close to being significant. Also, it implies that explosive and power training in concentric mode must be focused in order to increase vertical jump performance. Also, eccentric mode must be included in training to safeguard landing and avoiding injuries.

Keywords: Isokinetic strength, Knee extensor, Vertical Jump, Sergeant jump test.

Introduction
Volleyball is among one of the popular team sports played all around the globe (Kilik *et al*., 2017). The game of volleyball is characterized by explosive movements of the players during spiking and blocking as well as quick reflexive and coordinated actions of players during receiving and setting the ball for attack. These motor actions require players to perform bipodal vertical jumps, countermovement jumps with arm swing, occasional one-legged jumps in attack and diving to receive the ball. No. of researchers have attributed players' anthropometry, lower limb strength, strength-endurance, and power (Carlock *et al*. 2004; Son *et al*. 2018) [4, 14] among others as determinants of vertical jump performance.

Muscular Power is the ability of an individual to overcome resistance in shortest time. High levels of speed, strength and power (Harrison *et al*. 2013) [8] in the lower extremity muscle groups determine the maximum jumping performance. Since the vertical jump is performed by collective efforts of muscles of hip, knee, and ankle joint, these muscles become prime candidates for assessment and training of vertical jump in sports like volleyball, basketball, and soccer (Tsiokanos *et al*. 2002; Son *et al*. 2018) [17, 14]. Recently, Knee extensor and ankle planterflexor muscles have received much attention in those sports which require explosive vertical jumping movements because of their involvement in vigorous extension of knee and production of large ground reaction force respectively. The strength contribution of muscle groups of hip, knee and ankle related to vertical jump ability have been reported to be 28, 29 and 43 percent respectively (Vanezis and Lees, 2005) [18]. Also the strength characteristics of lower limb muscles rather than jumping technique affect vertical jump performance (Harrison *et al*. 2013; Suchomel *et al*. 2016) [8, 16].

The vertical jump test has since long been used to measure lower extremity and especially knee extensor muscles' power output (Suchomel *et al*. 2015) [15]. A common and widely used method of assessment of jumping ability is "Sergeant Vertical Jump Test" whose reliability and validity are well established for sporting population.

A new power and strength evaluation method in the form of maximum isokinetic strength has emerged recently (Bulgan, 2016) [3]. Isokinetic tests involve unilateral isolated active muscle group strength assessments with limitations of the joint angular velocity (Koutsioras *et al*. 2009) [11] using isokinetic dynamometers resulting in maximal torque output exerted by isolated muscle groups around the hip, the knee and ankle joints at various angular velocities. The objective assessment of muscle function using isokinetic measurements allows the production of comparable and reproducible results (Tsiokanos *et al*. 2002) [17].

Although the relationship between vertical jump height and isokinetic strength of the lower limbs has been well studied (Byrne and Eston 2002; Chang *et al*. 2015; Gantiraga *et al*. 2006; Harrison *et al*. 2013) [5, 8], there is a lack of evidence to show which (concentric or eccentric) mode of isokinetic strength training is best related to vertical jump performance. Therefore this study was aimed to investigate the relationship between maximum concentric/eccentric isokinetic strength of knee extensor muscle group and vertical jump performance.

Methods & Materials

Participants

Eighteen players from Under-20 Indian volleyball team (age 18.05±0.72yrs; height 192.17±5.83cm and body weight 77.64±7.29 kg) participated in the present study. The participants had not had any lower extremity injuries before. The study was conducted consistent with the recommendations of the Declaration of Helsinki. Written consent was obtained from all the students. Students performed the tests in the exercise physiology laboratory over a week period.

Design of the study

Vertical Jumping Test

The subjects performed the Sergeant Jump (SJ) as vertical jumping test. 5 min jogging and 5 min dynamic stretching were applied for warm up before the test. By standing by the side of the wall, standing height was marked initially using contrast marking powder with hand vertically extended. 3 trials of SJ were performed from semi-squatting position with the knees flexed to approximately 90° with arm swing allowed and marked again on the wall. The average of difference between standing height and maximum jump height was recorded as vertical jump performance.

Isokinetic Test

The isokinetic concentric strength of the knee extensor muscles of both legs was assessed by using isokinetic dynamometer (Cybex Humac Norm Isokinetic system) (Li *et al*. 1996) [12]. Since the test was performed immediately after vertical jump test, no need of warm-up was felt. Each participant was tested in the seated position and fixed to the seat from their body, waist, and femur. The axis of rotation of the knees (lateral femoral epicondyle) was aligned with the mechanical axis of the dynamometer, and the resistance thigh pad was placed just proximal to the knee. Moreover, they held the handles of the seat on both sides to prevent the freeness of the arms and had support from the seat (Bulgan, 2016) [3]. Concentric/eccentric peak torque of the Quadriceps Muscles of dominant and non-dominant leg of the participants was evaluated at angular velocities of 60°·s-1, 90°•s-1 and 120°·s-1. Before testing, the subjects were allowed 5 familiarization trials. Then, the subjects performed 3 maximal concentric/eccentric knee extension at 60°·s-1, 90°•s-1 and 120°·s-1 for both legs. Subjects were allowed 3- min rest between each protocol. Isokinetic peak torque (PT), peak torque/body weight (PT/BW) of Quadriceps Muscles (N·m) were evaluated for each player.

Statistical Analysis

Statistical analysis was handled by using the Statistical package for Social Sciences 22.0 (SPSS. IBM, New York). The average and standard deviation (SD) of the data were calculated as descriptive statistics. Pearson Correlation analysis was used to determine the relationship between maximum isokinetic strength and jump performance. The level of significance was set at p<0.05.

Results

The descriptive statistics for the present data set is shown in Table 1.

The age, height, body weight, vertical jump and BMI are shown in table 1. Also, the table 1 contains the mean and standard deviation values of concentric and eccentric knee extensor strength values at 60^0/s, 90^0/s and 120^0/s for dominant and non-dominant leg.

Table 1: descriptive statistics

Variable			Mean	Std. Deviation
Age			18.05	0.73
Height			192.17	5.83
Body weight			77.64	7.29
BMI			21.05	2.00
Vertical Jump			62.81	5.33
Left Leg	60degree/sec	CONC	328.78	69.15
		ECC	408.94	73.69
	90degree/sec	CONC	296.61	57.15
		ECC	414.50	111.03
	120degree/sec	CONC	260.89	49.79
		ECC	426.50	117.58
Right Leg	60degree/sec	CONC	287.72	62.08
		ECC	384.94	106.17
	90degree/sec	CONC	262.22	73.62
		ECC	382.78	98.10
	120degree/sec	CONC	237.00	71.60
		ECC	381.83	107.60
N			18	

CONC= Concentric

ECC = Eccentric

As evident from analysis, vertical jump was significantly correlated to concentric knee extensor strength in both legs at 1200/s (LQ r= 0.582; p<0.05; RQ r= 0.519; p<0.05) (Table 2). Also evident from Table 2 is the fact that although the relationships between vertical jump and concentric knee extensor strength at other angular velocities (600/s, 900/s) are insignificant, they were close to being significant at p<0.05. All the relationships between vertical jump and eccentric knee strength in both legs were insignificant (Table 2).

Table 2: Product Moment Correlations between vertical jump and Peak Torque/BW at Con/Ecc knee extensor strength at various angular velocities

	Con60^0/s		**Con90^0/s**		**Con120^0/s**		**Ecc60^0/s**		**Ecc90^0/s**		**Ecc120^0/s**	
	LQ	**RQ**	**LQ**	**RQ**	**LQ**	**RQ**	**LQ**	**RQ**	**LQ**	**RQ**	**LQ**	**RQ**
VJ												
r	.461	.438	.468	.434	.582	.519	.025	.000	.154	-.038	.046	.029
sig.	.054	.069	.050	.072	.011*	.027*	.922	.999	.541	.880	.856	.910

*Correlation significant at 0.05.
VJ= vertical jump
Con60^0/s= Concentric contraction at angular velocity 60^0/s
Con90^0/s= Concentric contraction at angular velocity 90^0/s
Con120^0/s= Concentric contraction at angular velocity 120^0/s
Ecc60^0/s= Eccentric contraction at angular velocity 60^0/s
Ecc90^0/s= Eccentric contraction at angular velocity 90^0/s
Ecc120^0/s= Eccentric contraction at angular velocity 120^0/s

Discussion

Vertical jump performance may be considered a partial predictor of knee strength and vice-versa (Boling *et al*. 2013) [1]. Koutsioras *et al*. (2009) [11] stated isokinetic muscle strength to be important in different functional performances (Koutsioras *et al*. 2009) [11] and the results from the present study support the claim from many studies (Cinar-Medeni *et al*. 2015; Chang *et al*. 2015; Menzel *et al*. 2013) [6, 5, 13]. The eccentric knee extensor strength was not significantly correlated to vertical jump performance. One possible reason for the finding might be the selected speed protocol (60^0/s, 90^0/s and 120^0/s) because Harrison *et al*. (2013) [8] found positive correlations at 240^0/s. Also, since the players selected in the study were below 20 years and it has been shown that age affects eccentric performance (Kellis *et al*. 2001) [9]. Bolgan (2016) reported high relationship between isokinetic Peak torque/BW and squat jump height. He also reported that the relationship of jump height to knee extension strength is greater than hip extension which was attributed to highly elastic knee extensor tendons and muscles which produce additional force through elastic recoil (Bolgan, 2016; Harrison *et al*. 2013) [8]. Also, the muscular fatigue before strength testing has been considered a covariate in isokinetic testing (Bryne & Eston, 2002) [2].

The present study support the claim about vertical jump height being correlated to concentric knee extensor strength at various angular velocities (Chang *et al*. 2015) [5]. This might have practical implications in coaching and training as concentric contraction of muscle is focused during early stage of training (Tsiokanos *et al*. 2002) [17]. Also, the correlation coefficients between the vertical jump and the isokinetic concentric parameters were significant with highest being observed at 120°·s-1 (r=0.0.582; $p<0.05$) (Tsiokanos *et al*. 2002) [17].

Also, the correlation coefficients were significant at 120^0/s angular velocities which once again reiterate the significance of training at high angular velocities to improved jumping performances and increased peak torque in knee extensor muscle groups (Harrison *et al*. 2013) [8].

Conclusion

Knee extensors are among important factors that play a significant role in jumping performance. Isokinetic concentric and eccentric strength are important phases of sergeant jump and overall vertical jump performed in volleyball. Although, in vertical jump performances, potential energy of eccentric contraction is transferred to concentric contraction, the eccentric strength phase is insignificant to aid concentric strength in sergeant jump and so the eccentric strength was not significantly related to jump height.

Recommendations

Although the isokinetic eccentric knee extensor strength was not significantly related to vertical jump height, it has got its significance in landing biomechanics and thus in order to prevent injuries it becomes important to train quadriceps muscles eccentrically. Also isokinetic concentric strength was related to jumping performances and thus should be the focus of training for maximum reach.

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