European Journal of Physical Education and Sport Science
ISSN: 2501 - 1235
ISSN-L: 2501 - 1235
Available on-line at: www.oapub.org/edu

doi: 10.5281/zenodo.1411064 Volume 4 | Issue 10 | 2018

RELATIONSHIP OF CORE STRENGTH AND ISOKINETIC KNEE STRENGTH WITH VERTICAL JUMP PERFORMANCE IN VOLLEYBALL

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Abstract:

Background: The game of Volleyball requires the players to perform dynamic movements in receiving the ball and performing explosive movements in spiking and blocking. Vertical jump (VJ) becomes one of the basic motor ability in volleyball owing to its frequent involvement during spiking, blocking, and setting the ball for attack. Although considerable work has been done, the relationship between core strength (Trunk Flexion (TF) & Back Extension (BE)) and vertical jump remains unclear. Thus, the present study was aimed at finding relationship between core strength-endurance and vertical jump performance. **Method:** 20 male players (Age=18.05±0.76 years; Height=192.75±5.88cm; Weight=77.67±7.37kg) from Indian National U-20 Volleyball team were tested on an Isokinetic Dynamometer at $60^{0}*s^{-1}$, $90^{0}*s^{-1}$ and $120^{0}*s^{-1}$ angular speeds for strength testing, on DAVID systems for trunk flexion and back extension and on sergeant test for vertical jump. **Results:** Core strength-endurance (TF & BE) and isokinetic concentric Quadriceps strength at $120^{0}*s^{-1}$ (CDQ120) for dominant leg were significantly positively correlated to vertical jump (TF vs VJ: r=0.507, p=0.023; BE vs VJ: r=0.453, p=0.045; CDQ120 vs VJ: r=0.595, p=0.006) while isokinetic strength for non-dominant leg approximated significance with increasing velocities. Also, core strength (TF & BE) was significantly positively related with FlightTime (FT) (TF vs FT: r=0.497, p=0.026; BE vs FT: r=0.568, p=0.009). **Conclusion:** The significant positive correlation of core strength with vertical jump and FlightTime establishes core strength as an integral component of sports training in Volleyball. Although, eccentric quadriceps strength and hamstring strength were not positively correlated to vertical jump, they help in safe landing mechanism and reduce injury-risks. The small sample size of the study warrants further investigations with larger sample size to confirm the findings.

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Keywords: core strength, isokinetic knee strength, vertical jump, flighttime, isokinetic dynamometer

1. Introduction

Volleyball is among one of the popular sports played worldwide.[1,2,3] The game of Volleyball requires the players to perform dynamic movements in receiving the ball and performing explosive movements in spiking and blocking. Vertical jump is considered as one of the basic motor ability in volleyball owing to its frequent involvement during spiking, blocking, and setting the ball for attack.[4]

Muscle strength-endurance is an important fitness component which determines sports performance.[5] Muscular Power is the ability of an individual to overcome resistance in shortest time. 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 in sports like volleyball, basketball, and soccer.[6,7] The Isokinetic assessment of strength has gained popularity over the years due to its resemblance to the actual movement and greater involvement of muscles throughout the range of motion as opposite to isotonic and isometric movement.[5,8,9,10] Isokinetic dynamometers are used to measure peak torque, average power and total work done at different speed protocols at different body joints.

Recently, Knee extensor and ankle planterflexor muscles have received much attention in those sports which require explosive vertical jumping movements[11] because of their involvement in vigorous extension of knee and production of large ground reaction force respectively. Also, core stability has emerged as a new determinant of vertical jump performance due to its role in anchoring the coordination in explosive movements of upper and lower extremities.[12,13,14,15,16,17] Although trunk flexion has shown insignificance with vertical jump performance[15] but since the game of volleyball requires explosive vertical jumps coupled with dynamic shoulder movement, the "core" becomes promising candidate component for further investigation. Core might also contribute in keeping body sail in air for fractionally longer thus benefitting attackers to adjust their spike. The vertical jump is assessed by many methods.[3,18] Sargent Jump has been a consistent means of measuring vertical jump performance as maximum vertical jump height minus standing height.[19]

Since, to date, no clear consensus on association between vertical jump performance in Volleyball and core strength-endurance exists, the purpose of the present study was therefore to investigate the relationship of isokinetic concentric and eccentric knee strength and core strength-endurance with vertical jump performance and secondarily to assess any relationship between core strength-endurance and time of stay in air (FlightTime).

2. Methods and Materials

The study aimed to investigate the relationship of isokinetic concentric knee extensor strength and core strength-endurance with vertical jump in Volleyball.

2.1 Subjects

For the purpose of the study, 20 players (male, age- 17 to 20 years) from Indian National Under-20 Volleyball team were selected purposively in May-July, 2018. They trained three-session a day, 90-120 minute per session. All players were healthy and reported no history of injury (hip, knee and ankle) and were equally motivated to participate in the study. All the players were informed about the purpose of the study and duly filled informed-consent were obtained from selected players. The protocol of research on human subjects was reviewed and approved by an ethical commission within institution in accordance with the Declaration of Helsinki and written consent was obtained from concerned team officials at the start of the study[39].

2.2 Design

The participants were tested on anthropometric variables: height and weight according to International Standards for Anthropometric Standards[20] (ISAK, 2001) and BMI was calculated. Thigh circumference was measured at upper thigh just below the buttocks. Calf girth was measured at widest girth midway between the ankle and knee. The participants performed warm-up on treadmill at 7kmph for 5 minutes followed by dynamic stretching exercises for 5 minutes.

2.3 Vertical jump

The procedure was explained and demonstrated to them. The subjects performed sergeant jump using wall mounted inch tape. First they stood tall by the side of the wall and extended dominant hand fingertip to mark standing height. Next, they performed a countermovement consisting of bending knees and hips while at the same time flexing the trunk. Each subject was instructed to lower themselves to a most comfortable point at the same time moving their arms back into hyperextension. Then the subjects would leap vertically as high as possible using both arms and legs, assisting the body upwards and the highest point reached was marked and recorded.[19] 3 trials were allowed.

Vertical jump was calculated using following equation:

Vertical Jump= Max. Jumping Height – Max. Standing Height

Average of 3 trials was recorded as score on vertical jump performance.

2.4 Flight Time

During vertical jump, the Flight Time was measured with Digital Stopwatch (Casio HS-80TW Digital Stopwatch) from the moment of toe-off to the moment of toe-strike on the ground. The average of 3 trials was calculated and recorded.

2.5 Isokinetic knee strength testing

The knee strength of dominant and non-dominant leg was assessed with Humac Norm Testing & Rehabilitation System (CSMi Medical Solutions, USA).[21] Concentric and eccentric peak torque of the Quadriceps, Hamstring Muscles of dominant and non-dominant leg of the participants was evaluated at angular velocities of $60°*s^{-1}$, $90°*s^{-1}$ and $120°*s^{-1}$. The participants were explained the procedure. 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.[22]

Before testing, the subjects were allowed 3 familiarization trials. Then, the subjects performed 5 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. Since, relative isokinetic Quadriceps strength was considered a better indicator of leg strength as compared to absolute isokinetc Quadriceps strength thus eliminating the effect of body weight in strength testing, isokinetic Peak Torque/ Body Weight (PT/BW) of Quadriceps and Hamstring Muscle (N*m) was evaluated for each player.

2.4 Core strength-endurance testing

Core Strength-endurance was assessed with DAVID R-2100 Lumbar-Thoracic Extension/Flexion System (DAVID Health Solutions, Finland). First, the maximum voluntary contraction (MVC) was assessed with 1RM. 60% MVC was used for testing core strength-endurance.[23] The participant was motivated to perform maximum repetitions until exhaustion at 60% MVC for both trunk flexion and back extension.

2.5 Statistical Analysis

Data were collected and analyzed with SPSS 22.0 (IBM Corp. USA). The mean and standard deviation were calculated for all the variables. Normality was assessed using Shapiro-Wilk test of normality. Bivariate Pearson Moment Correlation (r) was used for establishing relationship between vertical jump and Isokinetic eccentric and concentric knee flexor and extensor strength, Core strength (trunk flexion and back extension), thigh and calf girth. Level of significance was set at 0.05.

3. Results

Descriptive statistics (Mean, Std. Deviation, and Shapiro-Wilk Normality test) for Age, Height, Weight, ThighGirth, CalfGirth, BMI, Trunk Flexion, Back Extension, Flight Time and Vertical Jump performance was reported (Table 1). Shapiro-Wilk test for normality shows that data on Age violates the assumption of normality at 0.05 level of significance due to the participants being selected from specific age group (17-20 yrs). All other variables were normal and Pearson Product Moment correlation was calculated.

Table 1: Descriptive Statistics

	Mean	Std. Deviation	Shapiro-Wilk Test for Normality		
			Statistics	df	Sig.
Age (in years)	18.05	0.76	0.816	20	0.002
Height (Ht) (in cm)	192.75	5.88	0.915	20	0.078**
Weight (Wt) (in kg)	77.67	7.37	0.916	20	0.082**
Thigh Girth (TG) (in cm)	52.53	2.78	0.926	20	0.132**
Calf Girth (CG) (in cm)	36.38	2.15	0.968	20	0.707**
BMI	20.93	1.98	0.959	20	0.519**
Trunk Flexion (TF) (in no.)	44.90	6.86	0.910	20	0.064**
Back Extension (BE) (in no.)	59.25	12.98	0.957	20	0.494**
Flight Time (FTime) (in sec)	.754	.123	0.956	20	0.459**
Vertical Jump (VJ) (cm)	62.86	5.18	0.963	20	0.616**

Table 2: Pearson Product Moment Correlation (r)
between Vertical jump and Isokinetic Concentric Leg strength

Vertical Jump	Concentric Strength											
	Dominant Leg						Non-dominant Leg					
	Quadriceps			Hamstring			Quadriceps			Hamstring		
	60^0	90^0	120^0	60^0	90^0	120^0	60^0	90^0	120^0	60^0	90^0	120^0
Pearson r	.391	.427	.595	-.196	.052	.080	.418	.395	.430	.064	.140	.152
Sig.	.088	.061	**.006***	.408	.827	.737	.066	.084	.058	.790	.556	.524
N	20											

*significant at 0.05 level of significance.

Table 3: Pearson Product Moment Correlation (r)
between Vertical jump and Isokinetic Eccentric Leg strength

Vertical Jump	Eccentric Strength											
	Dominant Leg						Non-dominant Leg					
	Quadriceps			Hamstring			Quadriceps			Hamstring		
	60^0	90^0	120^0	60^0	90^0	120^0	60^0	90^0	120^0	60^0	90^0	120^0
Pearson r	-.003	.101	-.029	-.274	-.366	-.074	-.088	-.079	-.029	-.166	-.109	-.074
Sig.	.989	.672	.903	.242	.113	.758	.712	.740	.903	.483	.647	.758
N	20											

From Table 2 and 3, it was evident that only isokinetic concentric Quadriceps strength at 1200*-1s for dominant leg was significantly related with vertical jump performance ($p<0.05$). Also, although not significantly related to vertical jump, isokinetic concentric Quadriceps strength for dominant leg at 600*s-1 and 900*s-1 was approximating significance for relationship to the vertical jump performance. Likewise isokinetic concentric Quadriceps strength for non-dominant leg also exhibited a trend towards being significantly related to vertical jump performance with increasing angular speeds. Also, no speed protocols for isokinetic eccentric Quadricpes strength were significantly related to vertical jump performance. Neither the concentric nor the eccentric Quadriceps strength for non-dominant leg was significantly correlated to vertical jump. Also, Hamstring strength of dominant and non-dominant leg was not significantly related to vertical jump at any speed protocol in concentric or eccentric contraction.

Table 4 summarizes the correlation of all the variables with Vertical Jump performance and the significant relationship of Flight Time with Vertical jump performance ($p<0.05$). Also, found were the significant correlations of Flight Time with Trunk Flexion, Back Extension, Concentric Dominant leg Quadriceps and Concentric Non-Dominant leg Quadriceps strength ($p<0.05$).

Table 4: Pearson Product Moment Correlations (r) with corresponding p-values

	Vertical jump	Height	Weight	Thigh girth	Calf girth	Trunk flexion	Back extension	Flight time	CDQ120	CNQ120
Vertical jump Pearson r	1									
Sig (2-tailed)										
Height Pearson r	-.257	1								
Sig (2-tailed)	.274									
Weight Pearson r	-.024	.312	1							
Sig (2-tailed)	.920	.181								
Thigh girth Pearson r	.441	-.332	**.596****	1						
Sig (2-tailed)	.052	.152	**.006**							
Calf girth Pearson r	.280	-.163	**.667****	**.628****	1					
Sig (2-tailed)	.233	.492	**.001**	**.003**						
Trunk flexion Pearson r	**.507****	-.046	.231	.293	.412	1				
Sig (2-tailed)	**.023**	.846	.328	.209	.071					
Back extension Pearson r	**.453****	.336	.261	.202	.129	**.578****	1			
Sig (2-tailed)	**.045**	.148	.267	.394	.587	**.008**				
Flight time Pearson r	**.525****	.116	.125	.150	.156	**.497****	**.568****	1		

Sig (2-tailed)	**.017**	.627	.599	.529	.511	**.026**	**.009**			
CDQ120 Pearson r	**.595****	-.163	-.076	.302	-.069	.326	.402	**.535****	1	
Sig (2-tailed)	**.006**	.491	.751	.196	.774	.160	.079	**.015**		
CNQ120 Pearson r	.430	.057	.282	.351	.213	.417	.391	**.510****	**.806****	1
Sig (2-tailed)	.058	.810	.229	.129	.367	.067	.089	**.022**	**.000**	

** significant at 0.05 level of significance.
CDQ120= Concentric Dominant Leg strength at 120 degree speed
CNQ120= Concentric Non-Dominant Leg strength at 120 degree speed

4. Discussion

Vertical Jump is a foremost important motor fitness component required in such games as Basketball, Volleyball, Soccer and many others. Anthropometric properties along with appropriate physical fitness components are important prerequisites for outstanding performance of sports skills and play a distinguished role in sports' successful achievements.[24] In the sport like Volleyball where a high power-output demand is placed during repeated attacking and defensive vertical jumps, vertical jump performance becomes prime focus component of research and training.

The results from present study comply with Fattahi et al.[24] who reported lower limb strength and abdominal endurance to be important factors determining vertical jump performance. In our study, we found that vertical jump was significantly correlated to isokinetic concentric Quadriceps strength of Dominant leg at increasing angular speeds ($60^{0*}s^{-1}$, $90^{0*}s^{-1}$ & $120^{0*}s^{-1}$)[25] whereas it showed trend towards being significant for Non-Dominant leg Quadriceps strength which is consistent with the idea of equal bilateral training. According to our results, amongst the parameters included in the study, the most important ones related to vertical jump performance turned out to be Isokinetic Concentric Quadriceps strength of Dominant as well as Non-Dominant leg and core strength-endurance. Also, not less important are the thigh Girth and Calf Girth although not been significant[24] since the amount of vertical jump depends greatly on vertical ground reaction force and greater physiological cross-sectional area of muscle determines power.[26,27]

Core strength was also significantly correlated to vertical jump performance[28] in contrast to the findings of Ozmen[29] and Nesser et al.[13] who stated that trunk flexion was negatively related to vertical jump performance in Soccer. The method of core strength assessment might be a major factor for such relationship with motor fitness performance during sport[12,13,30,31,32,33] due to a lack of test specificity. Theoretically, Core muscles contract isometrically to provide core stability during movement but during explosive jumps, their muscle activation pattern remains relatively unknown, thus emphasizing the need for further research. Also, time from toe-off to toe-strike (Flight Time) was also significantly positively related to vertical jump, Isokinetic concentric quadriceps strength in Dominant and non-dominant leg and Core strength-endurance (trunk flexion and back extension) thus again demonstrating importance of Core training in vertical jump performance.[34] A possible reason, although unexplained, why the high Flight Time is generally considered beneficial in Volleyball is that it provides fractional advantage to the players to adjust their attack according to opponent players' position on court and thus deceive opponent defense.

Although the isokinetic eccentric Quadriceps strength of Dominant and Non-Dominant leg was not related to vertical jump performance but this makes this strength no less important in training.[35,36,37,38] Also, no significant relationship was found between vertical jump and Hamstring strength in Dominant and non-dominant leg. Eccentric strength in knee has been related to safe and efficient landing mechanisms.

4.1 Limitations

Although the results of the study are promising, these must be interpreted with caution as the sample size was small (20) thus necessitating further research with large samples to validate these findings. Also, the positional differences in Volleyball (spiking, setting, blocking and libero) were not taken into consideration while analyzing the data and there might be differences in motor fitness and anthropometric parameters owing to their playing position, thus further investigations are warranted to establish the findings from the present study.

5. Conclusion

The competitive performance in the game of Volleyball largely depends on vertical jump that puts repetitive high power demands on the lower limbs to propel the body up in the air. Therefore, the factors related to vertical jump become critical in sports training. The present study proposes anthropometric measures (thigh and calf girth), Isokinetic Quadriceps concentric strength of Dominant and Non-Dominant leg and core strength-endurance as possible factors related to vertical jump performance. In the light of limitations of the present study, further investigations are necessitated to cement these findings. Although the significant findings of the present study might be encouraging, but since, Pearson correlation (r) is often misleading and may not explain cause-effect relationship between variables of interest, higher order multivariate analysis (i.e. Path Analysis, Structural Equation Modeling, Multiple Regression) should be employed in future studies to validate these results.

5.2 Recommendations

Based on the findings of the study on the relationship of core strength-endurance and isokinetic quadriceps strength with vertical jump and of flight time with core strength-endurance, these factors should be included into motor fitness training for Volleyball. Also, regression models can be developed to find which variables explain most variance in vertical jump performance. Also, Path Analysis can be employed with large sample (>200) size to investigate direct and indirect effects of core strength-endurance on vertical jump and flight time.

Acknowledgements
A word of gratitude is devoted to Prof. Abhimanyu Singh (BHU, Varanasi) for his consistent support and valuable guidance during the testing and documentation and Mr. R.K. Shukla (Exercise Physiology Lab Manager, LNIPE, Gwalior) for his valuable time and support during the course of work. We also thank lab staff and colleagues for their help during various phases of compilation of the article.

Conflict of interest
Authors state no conflict of interest.

Disclosure statement
No author has any financial interest or received any financial benefit from this research.

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