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Original Article

Physiology Section

Development of a Model to Predict the Jumping Performance in Elite Male Volleyball Players: A Cross-sectional Study

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ABSTRACT

Introduction: Vertical Jump Performance (VJP) has been identified as a significant characteristic in elite volleyball players and is an essential component for successful volleyball practice.

Aim: To better understand volleyball players' anthropometric and physical fitness characterstics and to predict jumping performance of the players using these variables.

Materials and Methods: For this cross-sectional study, 20 Indian junior male volleyball players were randomly selected from a coaching camp organised at Lakshmibai National Institute of Physical Education (LNIPE), Gwalior, Madhya Pradesh, India from May 2018 to July 2018. All the subjects were measured for VJP, selected anthropometrics {Right Thigh Girth (RTTG), Left Thigh Girth (LTTG), Average Thigh Girth (ATG), Right Calf Girth (RCG) and Left Calf Girth (LCG), Average Calf Girth (ACG)} and physical fitness characteristics {Flexibility (FLEX), Left Calf Strength Endurance (LTCSE), Right Calf Strength Endurance (RTCSE), speed, Core Endurance Abdomen Flexion (CEAF), Core Endurance Back Extension (CEBE), Low Body Explosive Power (LBEP) and Upper Body Explosive Power (UBEP), Cardiorespiratory Fitness (CF), VO_2 max, Abdominal Endurance (AE). The Subset regression analysis method was used to fit the appropriate linear regression model, while R-Square and Akaike Information Criterion (AIC) were used to identify a better model for a proper explanation of the vertical jumping performance of volleyball players, and a level of significance was set at the 0.05 level.

Results: The volleyball players included had an average age of 18.05±0.76 years. The results revealed that CEBE (β=-0.1525, p=0.0199), FLEX (β=1.0842, p=0.0001), LBEP (β=8.1636, p=0.0018), right (β=-0.2417, p=0.0125), and LTCSE (β=0.5143, p=0.0012), VO_2 max (β=-9.2467, p<0.001), and AE (β=1.0009, p<0.001) were the variables with the highest predictive power for jumping performance.

Conclusion: The current study identifies CEBE, FLEX, LBEP, RTCSE and LTCSE, VO_2 max, and AE as critical factors for improving jumping performance, emphasising the importance of considering multiple anthropometric and physical fitness variables when identifying talent and designing a volleyball training programme.

Keywords: Athletic Performance, Humans, Vertical jumping

INTRODUCTION

Volleyball is a highly dynamic sport defined by a high rate of movement repetition in a short period, as well as explosive motions such as jumping and sprinting on the field [1]. It is also identified as one of the most explosive and fastest sports, requiring excessive muscular strength, power, speed, and agility [2]. In a five-set volleyball game, it has been shown that 250-300 acts of high-intensity and explosive activities are conducted at the highest level [3], including intense landing following a vertical jump used for techniques like serve, block, and attack [4,5].

Volleyball performance is typically determined by a player's ability to project themselves into the air during both attacking and defending actions. The effectiveness of the opponent's attacking skill is related to the vertical jump height during a block jump. Vertical jump height helps the player make contact with the ball over the net while serving or spiking, providing for greater spiking or serving angles [6]. Vertical jump height has been associated with an increased risk of patellar tendinopathy, despite success in sports [7], the most frequent overuse ailment among volleyball players. These findings emphasise the need to measure and enhance volleyball jumping abilities.

Anthropometric characteristics and physical fitness are essential for successful sports participation. Anthropometric variables can change as people grow, and physical abilities can be improved with adequate training. In this regard, determining specific anthropometric traits that distinguish successful players from unsuccessful ones is critical. In volleyball, earlier research has shown that anthropometric parameters are significantly correlated with VJP [8,9], and different positions have varied anthropometric characteristics [10,11], as well as physical fitness characteristics [6,11].

Despite research on anthropometric and fitness factors in volleyball players, information on such parameters, especially in junior (aged under 19 years) Indian volleyball players, is limited. The current study was designed to fill gaps in the literature. Therefore, the present study was conducted to better understand volleyball players' anthropometric and physical fitness characteristics and to predict jumping performance using these variables.

MATERIALS AND METHODS

In the present cross-sectional study, twenty Indian junior male volleyball players were chosen at random from a coaching camp held at LNIPE, Gwalior, Madhya Pradesh, India, from April 2018 to July 2018, using simple random sampling.

Procedure

Following the appropriate testing procedure, data on anthropometry and physical fitness, were collected.

All of the subjects were living on the LNIPE premises and had similar food arrangements. Prior to administering tests, the researcher met with the authorities and subjects to explain the requirements of the testing procedures in full so that there would be no confusion about the effort expected of them. All of the participants voluntarily agreed to take part in the study, understood the requirements, and signed a consent form acknowledging their understanding of the procedures. The study was conducted under the supervision of the Volleyball

Federation of India (VFI) as part of the routine evaluation procedure, and a consent was obtained from participants. All of the players were in good health, had no prior injuries, and were motivated to participate in the examination. All of the exams were given between the hours of 9 to 11 am.

Measurement: Prior to the start of the investigation, all the instruments used in the study were thoroughly tested. The study participants' height (Ht), weight (Wt), Body Mass Index (BMI), RTTG, LTTG, ATG, RCG, and LCG, ACG, were taken as per the International Society for the Advancement of Kinanthropometry (ISAK) procedure [12]. At each site, three measurements were made, and the average value was taken for calculations. Following the completion of the anthropometric measures, each participant had a 5-minute warm-up to condition the body and minimise the chances of injury, followed by 5 minutes of dynamic stretching activities. Physical fitness characteristics, namely flexibility (FLEX), were measured using the sit and reach test [13] in centimetres, LTCSE, RTCSE, were tested using the calf raise test [14] in seconds, speed (SP) was determined using the '20 metres dash' test [15] through a SPEED digital hand-held stopwatch (Germany) in seconds, CEAF, CEBE were examined using trunk flexor and extensor tests in seconds [16], LBEP was measured using the standing broad jump test in centimetres, UBEP was tested with a medicine ball throw [17] in metres, CF was evaluated by running 2.4 kilometres distance on the track to the nearest second, VO_2 max was measured in liters/minute using a VO_2 Max Tracker ergo spirometre [18] (Morgan Scientific, Inc., Haverhill, MA, USA), which includes a pneumotach headpiece and quick oxygen and carbon dioxide analysers suitable for applying the 'breath-by-breath' approach to each exhalatory phase, AE was tested using the sit-ups test for 60 seconds, Jump Time (JT) and VJP were measured using standard procedures [19].

STATISTICAL ANALYSIS

The Shapiro-Wilk test of normality, histogram, and PP-plot were used to determine the data's normality in order to meet the assumption of using a parametric test. The sub-set regression analysis method was used to fit the appropriate linear regression model for choosing those explanatory variables which are responsible for better explaining the jumping performance of players. R-Square and AIC criteria were used to identify the best model for explaining the vertical jumping performance of volleyball players. Statistical analysis of the collected data was performed using the R-Software (version 4.1.0 for Windows).

RESULTS

[Table/Fig-1] revealed the descriptive statistics (mean and standard deviation) for demographic, anthropometric, physical fitness characteristics, and jump performance of junior Indian volleyball players, respectively. [Table/Fig-2] illustrates the concept of fitting an appropriate linear regression model. The subset regression method is used to generate models. The linear regression was carried out by selecting ten explanatory variables, and the best model was chosen by considering the values of R^2_p, AdjustedR^2_p, and AIC. In general, it is not a good idea to use R^2 (the coefficient of determination when considering the entire model) as a criterion for determining the number of regressors to include in the model. However, for a fixed number of variables p, R^2_p, can be utilised to maintain a superior model. Aitkin MA proposed a criterion for selecting the optimum value of R^2_0 (at a 5% level of significance), and he called any subset regression variable yielding R^2 larger than that optimum value R^2_0 =0.4830 a better fit [20].

In the fitted models, the first model has the best R^2_p among the other six fitted models that satisfy the Aitkin criterion, and the value of AIC for the first model is the lowest compared to the other models. Therefore, model one is the best fit for analysing vertical jumping performance.

Variables	Mean	Std. Deviation
Age (years)	18.05	0.76
Height (cm)	192.75	5.88
Weight (kg)	77.68	7.37
Body Mass Index (kg/m^2)	20.93	1.99
Right Thigh Girth (cm)	52.68	2.49
Left Thigh Girth (cm)	52.83	2.12
Average Thigh Girth (cm)	52.75	2.21
Right Calf Girth (cm)	36.30	2.17
Left Calf Girth (cm)	36.58	1.92
Average Calf Girth (cm)	36.44	2.00
Flexibility (cm)	22.42	6.08
Left Calf Strength Endurance (second)	36.10	13.40
Right Calf Strength Endurance (second)	36.95	14.47
Speed (second)	3.01	0.10
Core Endurance Abdomen Flexion (second)	34.40	16.55
Core Endurance Back Extension (second)	50.50	16.29
Lower Body Explosive Power (cm)	9.67	0.45
Upper Body Explosive Power (metres)	11.82	1.23
Cardiorespiratory Fitness (seconds)	9.51	0.55
VO_2 Max (litres/minute)	3.68	0.59
Abdominal Endurance (numbers/minute)	66.70	5.94
Jump Time (seconds)	0.75	0.12
Vertical Jump Performance (cm)	62.86	5.19

[Table/Fig-1]: Descriptive statistics.

Regression Models	Predicators	R^2	Adjusted R^2	AIC
Model 1	CEBE, FLEX, LBEP, LTCSE, RTCSE, VO_2 Max, AE	0.87	0.79	98.83
Model 2	CEAF, FLEX, LTTG, AE, SP, VO_2 Max	0.84	0.77	100.73
Model 3	CEAF, FLEX, JT, UBEP, RTCSE, RTTG, AE, CF, VO_2 Max, Wt	0.71	0.39	120.77
Model 4	FLEX, LTTG, AE, SP, VO_2 Max	0.81	0.74	102.41
Model 5	CEBE, FLEX, LBEP, JT, RTCSE, AE, CF, VO_2 Max, Wt	0.74	0.65	108.43
Model 6	FLEX, AE, SP, VO_2 Max	0.71	0.45	118.77
Model 7	CEAF, FLEX, RTTG, AE, SP, VO_2 Max	0.76	0.66	108.68
Model 8	FLEX, LTTG, AE, VO_2 Max	0.69	0.61	110.17

[Table/Fig-2]: Fitted linear regression models to measure the jumping performance of volleyball players.
Wt: Weight; RTTG: Right thigh girth; LTTG: Left thigh girth; FLEX: Flexibility; LTCSE: Left calf strength endurance, RTCSE: Right calf strength endurance; SP: Speed; CEAF: Core endurance abdomen flexion; CEBE: Core endurance back extension; LBEP: Lower body explosive power; UBEP: Upper body explosive power, CF: Cardiorespiratory fitness; VO2 max: maximal oxygen consumption; AE: Abdominal endurance; JT: Jump time

[Table/Fig-3] showed the values of R^2, adjusted R^2, and AIC as 0.8697, 0.7938, and 98.8343, respectively. For testing the significance of our model, the p-value is 0.0001813, which is less than 0.05, indicating that the fitted linear model is significant at a 5% level of significance.

The best-fitting model, Jumping Performance= -75.6016-0.1525(*CEBE*)+1.0842 (*FLEX*)+8.1636 (*LBEP*)+0.5143 (*LTCSE*)-0.2147 (*RTCSE*)-9.2467 (VO_2 *Max*)+1.009(*AE*), comprises CEBE, FLEX, LBEP, RTCSE, LTCSE, VO_2 Max, and AE.

DISCUSSION

Anthropometric and physical fitness characteristics are crucial for predicting athletic success [21,22]. Specific physical fitness characteristics and anthropometric profiles are required for peak

Coefficients	Estimates	Standard error	t-statistic value	p-value
Intercept	-75.6016	28.25	-2.676	0.02
CEBE	-0.1525	0.06	-2.682	0.01
FLEX	1.0842	0.24	5.318	<0.001
LBEP	8.1636	2.06	3.969	<0.001
LTCSE	0.5143	0.12	4.202	<0.001
RTCSE	-0.2417	0.08	-2.932	0.01
VO_2 Max	-9.2467	1.27	-7.248	<0.001
AE	1.0009	0.16	6.346	<0.001

[Table/Fig-3]: Estimates of the fitted linear regression model.

performance in particular sports [23,24]. The current study examines the relationship between anthropometric measurements, physical fitness variables, and the jumping performance of volleyball players. Individual relationship assessments do not provide a detailed picture, so an adjusted relationship was utilised in the analysis. All relevant predictors were included using subset regression models, resulting in eight separate models generated based on the order of model fitting according to AIC.

The model parameters were found to be significantly linked to the dependent variable, which was the jumping performance of volleyball players. The R-squared value of 0.87 indicates that 87% of the variation in players' jumping performance is explained by a total of seven explanatory variables. The coefficients' estimates indicate how changes in the predictors affect the jumping ability of volleyball players (Negative coefficient values suggest changes in jumping performance in the opposite direction). The sign of the regression coefficient indicates the direction of the correlation between the jumping performance of volleyball players and the explanatory variables.

The study revealed that core endurance is crucial for jumping performance, consistent with findings from a study by Bliven KCH and Anderson BE, which emphasised that core stability focuses on maintaining neutral spinal alignment, ideal trunk posture, and the transfer of loads along the kinetic chain to reduce the risk of injury [25]. Additionally, the model identified flexibility as a predictor of volleyball players' jumping performance. Stretching exercises are considered crucial for joint flexibility [26], enhancing an athlete's movement precision and allowing them to exert maximum force across the full range of motion [27,28].

The study also found that LBEP is related to jumping performance. Leg muscle power enables a muscle to produce the same amount of work in less time or with greater effort within the same time-frame, crucial for activities like sprinting, jumping [29], and volleyball [30]. Smith's study [31] highlighted that explosive strength in the lower extremities contributes to a good jump. Multiple studies [29,32] confirm the importance of the correlations between strength, power, and VJP [33].

The findings are also in line with a study conducted by Ben Ayed K et al., which examined the relationship between 5-jump test performance and two specialised laboratory tests for explosive power in volleyball players {Counter Movement Jump (CMJ) and Squat Jump (SJ)} [34]. Their findings revealed that 5-jump test performance was significantly correlated with SJ, peak jumping velocity, SJ height, peak power, peak jumping force, CMJ, peak jumping velocity, peak height CMJ, peak power, and peak jumping force. Calf Strength Endurance (CSE) is also found to be a factor in predicting jumping performance. A study conducted by Meylan C et al., found that having a high level of lower-body strength and explosiveness is vital for maximising sports performance [35]. Secomb JL et al., investigated connections between lower-body muscle structure and strength, characteristics assessed during a CMJ and SJ in adolescent athletes [36].

Their findings revealed that adolescent athletes with greater vastus lateralis and lateral gastrocnemius demonstrated stronger expression of dynamic and isometric force-producing abilities. This is most likely due to increased hypertrophy in the lower-body extensor muscles, which increases muscular cross-bridging. Furthermore, increased lower-body strength presumably allowed for stronger neuro-muscular activation. Similarly, a study [37] of adults' high-level volleyball practice found that "specific strength and physical traits were strongly linked with spike performance." VO_2 max was found to be inversely connected to jumping performance in the suggested model, which means that when jumping performance increases, VO_2 max falls, and vice versa. The fact that elite volleyball players do not have VO_2 max values as high as conventional endurance-trained athletes, despite the fact that playing volleyball requires an optimum degree of aerobic capacity, supports the findings [38]. Similarly, AE is related to jumping performance. This finding is supported by a study conducted by Lin H et al., which found that following rectus abdominis exhaustion, the maximum jump height is significantly lowered, resulting in a change in landing approach [39]. Because of abdominal exhaustion, the volleyball players were unable to squat to a lower position to gather energy before taking off, resulting in a decrease in maximum jump height and ankle moment, as well as a change in the load ratio of both legs during landing. Strong abdominal muscles are essential for maintaining stability during fast or intensive motions. According to research, the transverse abdominis and multifidus muscles contract before the lower limbs move to provide force to help support the spine and assist the lower limbs in providing strength during motions [39].

Limitation(s)

The present study was conducted using a small sample size, which poses limitations on the generalisability of the findings and necessitates the use of a higher alpha level. Furthermore, the scope of this study was restricted to male volleyball players within a certain geographical area. Consequently, further investigation is necessary to validate the present study's results through a more extensive and varied sample.

CONCLUSION(S)

This cross-sectional study found that core endurance, back extension, FLEX, LBEP, CSE, VO_2 max, and AE successfully predicted volleyball players' jumping ability. The variables chosen can be utilised to select outstanding junior male volleyball players. The outcomes of the current study provide helpful data that can be used by national federations, clubs, volleyball players, and coaches to establish the significance of anthropometric and physical fitness for player selections. Future research should emphasise the importance of upper body strength as well as technical and tactical abilities in male volleyball players during talent identification. The study could also help volleyball coaches to analyse their players' feedback and performance so that they can make better decisions.

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