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Original Article

Physiology Section

Anthropometric Basis of Vertical Jump Performance: A Study in Young Indian National Players

HANJABAM BARUN SHARMA[1], SHALINI GANDHI[2], KONTHOUJAM KOSANA MEITEI[3], JYOTI DVIVEDI[4], SANJAY DVIVEDI[5]

ABSTRACT

Introduction: Vertical Jump (VJ) is a good measure of athletic performance and occupational activities. Earlier studies reported conflicting results on anthropometric influence.

Aim: To evaluate the relationship between anthropometric characteristics and VJ in national level hockey and cycling players.

Materials and Methods: Fifty four (32 males) national level hockey and cycling players of 11-21 years were the volunteers. Following standard protocols, these variables were measured: VJ, Weight (WT), Height (HT), Trochanterion-Height (TH), Sum of Skinfold Thickness (SSF), Lengths [Acromiale-Stylion (AS) and Midstylion-Dactylion (SD)], Breadths [Biacromial (AB), Biiliocristal (IB), Biepicondylar Humerus (HB) and Biepicondylar Femur (FB)], Girths [Relaxed Arm (AG), Mid Thigh (TG) and Calf (CG)], Lower Back and Hamstring Flexibility (SR), Grip [Left Hand Grip (LHG) and Right Hand Grip (RHG)] and Back Strength (BS). International Society for the Advancement of Kinanthropometry (ISAK) procedures were followed for anthropometric variables measurement. Unpaired-'t'-test was used for comparison between genders. Pearson's correlation and multiple regression analysis were used to evaluate correlates and predictors of VJ respectively.

Results: Males had significantly higher VJ, HT, SD, AB and BS; but lower SSF, AS and TG. VJ correlated positively with age, WT, HT, SD, TH, girths, SR and strength among males; but only with WT and LHG among females. After controlling gender, TH and LHG predicted VJ significantly with 69% of total variance. HT, SSF and BS; and LHG were the significant predictors among males and females respectively.

Conclusion: Anthropometric and physiological variables like TH, grip, HT, skinfold and BS had major influence on VJ. The result might help in training-monitoring and player's selection.

Keywords: Anthropometry, Grip strength, Prediction equation, Skinfold thickness, Trochanterion height

INTRODUCTION

VJ is a good measure of strength, explosive power and muscle fiber composition [1] of lower limb joint musculatures, mainly of ankle, knee and hip joints [2-4]. It is one of the important tests for physical abilities [5] and has often been used as a measure of current and potential performance level of a player [6]. VJ performance and hence, leg power is essential for successful athletic performance, and also for daily activities and occupational tasks [7,8]. It is therefore considered an essential skill for better performance in various sports including football, basketball, diving, volleyball, high jump, hockey, cycling, sprinting, distance running etc. [8-11].

VJ height and performance is affected by various anthropometric, physiological and biomechanical factors [12-14]. Biomechanical factors include velocity, joint angle, centre of mass height, air resistance, force, acceleration, momentum and gravity etc. [15,16]. Some of the other important factors are muscle mass [17], flexibility, isometric muscle strength, age, height, weight [18] and level of expertise [13,19]. During VJ, the body is pushed upward against the gravity by powerful ground reaction developed as a result of muscular contraction from back extensors, gluteus maximus, quadriceps, hamstrings, gastrocnemius and soleus etc., and utilization of arm swing, trunk extension and head movements enhance the height jumped [20,21]. Apart from coordination of neuro-musculoskeletal systems, motivation and desire also regulate jump performance [6].

Although, many studies have been published to determine the anthropometric and physiological factors influencing VJ, there are always conflicting results with no good regression equation for predicting VJ yet to be identified [6,13,22]. Hence, this study was designed with the aim to evaluate the relationship between selected anthropometric characteristics and VJ.

MATERIALS AND METHODS

The present cross-sectional study was conducted under Sports Sciences and Fitness Centre, North-East Regional Centre-Sports Authority of India (NERC-SAI), Imphal, Manipur, India during a period of one month from September to October 2013. Twenty-two female and 32 male players from the department of hockey and cycling of the institute were the volunteers. The relatively small sample size was due to the unavailability of players satisfying our study criteria in the institute. Those who have participated in any recognized national level competitions or selected by the state sport federations/ associations for national meets, and belonging to 11-21 years were included. This was due to the fact that study was intended to be done only on elite, professional and national level players, as this was approved by the Institutional Research Committee. The players who had any health problem during the past 15 days or found unfit for any other reasons in the preparticipation physical evaluation and medical screening done by sports medicine physician of the institute were excluded.

After clearly explaining the purpose and procedures, all the tests and measurements were taken around the same time in the morning, two hours after a light breakfast, and after a sound sleep of about eight hours [10,11,23]. ISAK procedures were followed for measuring HT, WT, skinfolds, girths, and structural dimensions [24]. The measurements were taken from the right side of the body [25]. A stadiometer (Holtain Ltd., Crymych, Dyfed, UK) and a 50 cm wooden box were used to measure Standing Height (HT) and Sitting Height (SH) to the nearest 0.1cm [26]. Body Weights (WT) were measured to the nearest 0.1 kg using a calibrated digital scale with the subjects barefooted and wearing as light clothing as possible. Body Mass Index (BMI) was calculated as WT in kg divided by square of HT in meter. Six skinfold thickness (triceps, subscapular, supraspinale, abdominal, front thigh and calf) were measured using a Harpenden Skinfold Caliper. The sum of these six skin folds was used for analysis as an indicator of body fatness [27] and somatotype [25]. Two segmental lengths (AS and SD) and one height (TH) were measured using a segmometer (Rosscraft). Four breadths (AB, IB, HB and FB) were measured using large and small sliding calipers (Rosscraft). Three muscle girths (AG, TG and CG) were measured using a flexible and non stretching steel tape (Holtain Ltd.).

Technical error of measurement was used for evaluation of reliability, consistency and precision in measurement, and was under 1% for breadths and girths, 5% for skinfolds and 0.5% for height [25,28].

A hydraulic handgrip dynamometer (Baseline Hand Evaluation set 12-0100, NY 10602, USA), and an arm-leg and back pull electronic dynamometer (Strength Evaluation System IMI-1429, Indian Medico Instruments, Delhi) were used to measure grip strength of both side (Left, LHG and Right, RHG), and BS respectively, following the standard procedures [26]. VJ was conducted following the standard methodology after adequate motivation [29]. SR was measured using a sit-and-reach instrument (model-01285A, Lafayette Instrument Company, IN 47903, USA), following the standard methodology with the level of feet marked as zero [30,31]. Ethical committee of the institute approved the study, and a well informed written consent was taken from each participant.

STATISTICAL ANALYSIS

Standard descriptive statistics were determined and unpaired 't'-test was used for comparison of parameters between the genders, after normality checking was done using Shapiro-Wilk test. Pearson's correlation was used to evaluate association of VJ with various variables. Multiple regression equations were generated for predicting VJ such that most of the independent variables ß-weights were significant, with no multicollinearity, serial correlation and heteroscedasticity. Hierarchical multiple regression analysis and semi partial correlation R^2 were used to assess the effect of an independent variable above and beyond others on predicting VJ. The coding used for gender was: 0 for male and 1 for female. Statistical significance was chosen at p-value (2-tailed)≤0.5. Statistical Package for Social Science (SPSS) version 19 was used for data analysis.

RESULTS

The characteristics of the players are given in [Table/Fig-1]. Males had significantly higher VJ, HT, SH, SD, AB, LHG, RHG and BS; and lower SSF, AS and TG [Table/Fig-1]. VJ was found to have significant positive correlation with age, WT, HT, SH, SD, TH, AG, TG, CG, SR, LHG, RHG and BS among the males; and with WT and LHG among the females [Table/Fig-2]. When analysis was done with all the players combined, VJ correlated significantly and positively with WT, HT, SH, SD, TH, AB, LHG, RHG and BS; and negatively with SSF [Table/Fig-2].

However, among all the anthropometric variables, only TH and LHG accounted for significant contribution over the total variance in VJ, over and beyond those explained by gender, each other and other variables [Table/Fig-3a-d]. Hierarchical multiple regression analysis revealed that by adding LHG in the model [Table/Fig-3b], there was statistical significant improvement of 13.5% in the total variance in VJ accounted by gender and TH [Table/Fig-3a,b]. However, there was no statistically significant improvement in the total variance in VJ accounted for when BS and SSF were added subsequently [Table/Fig-3c,d]. The regression equation [Table/Fig-3b] had the highest adjusted R^2 (69%) with all its independent variables having significant unique contributions over the total variance in VJ.

LHG accounted for 13.47%, 3.39% and 3.20% significant unique contributions over the total variance in VJ over and beyond those explained by gender and TH; gender, TH and BS; and gender, TH, BS and SSF respectively [Table/Fig-3a-d]. The unique significant contributions by TH out of the total variance in VJ were 9.06%, 4.04%, 4.49% and 5.06% after controlling the overlapping effect of gender; gender and LHG; gender, LHG and BS; and gender, LHG, BS and SSF respectively [Table/Fig-3a-d]. Gender contributed statistically significant variance of 38.44%, 14.21% and 9% out of the total variance in VJ, after controlling for those contributed by TH; TH and LHG; and TH, LHG and BS respectively [Table/Fig-3a-c].

When analysis was done among the male players only, HT and SSF, and HT and BS together contributed a statistically significant variance of 65% and 58.9% out of the total variance in VJ with each having significant unique variance contribution [Table/Fig-3e,f]. Addition of BS and AS did not improve the predictive capacity of the equation [Table/Fig-3g] significantly [Table/Fig-3f,g]. Among the females, LHG and TH together contributed a statistically significant variance of only 26.6% out of the total variance in VJ with LHG having significant ß-weight [Table/Fig-3h].

Parameters	Mean±SD (Min.-Max.)		p-value
	Female (n=22)	Male (n=32)	
VJ (cm)	33.50±3.40 (26.67-42.00)	42.26±5.19 (34.29-52.00)	<.001**
Age (years)	15.86±2.59 (11.00-21.00)	15.38±1.83 (12.00-20.00)	.419
WT (kg)	49.99±7.17 (38.90-65.50)	53.80±7.66 (36.70-64.50)	.071
BMI (kg/m²)	20.95±1.93 (18.27-24.81)	20.10±1.79 (16.89-22.40)	.103
SSF (mm)	93.68±14.70 (69.00-121.00)	54.75±15.41 (31.00-91.00)	<.001**
HT (cm)	154.13±5.33 (145.80-163.10)	163.21±6.89 (147.40-176.40)	<.001**
SH (cm)	83.01±3.05 (76.00-87.50)	86.32±4.36 (74.50-94.60)	.003**
AS (cm)	68.68±7.86 (60.00-99.00)	55.37±22.2 (22.40-76.50)	.003**
SD (cm)	16.84±1.01 (15.00-18.80)	18.15±1.15 (16.10-20.30)	<.001**
TH (cm)	78.51±3.90 (71.30-86.00)	80.70±5.36 (62.10-89.70)	.113
AG (cm)	25.30±3.14 (22.00-36.00)	24.96±2.11 (21.50-29.00)	.639
TG (cm)	48.81±3.89 (42.70-55.50)	46.15±4.57 (38.50-59.00)	.030*
CG (cm)	34.35±2.46 (30.40-39.00)	33.81±2.24 (29.00-39.50)	.403
AB (cm)	34.90±3.36 (24.30-39.40)	36.99±3.47 (28.40-42.00)	.031*
IB (cm)	26.84±2.19 (22.00-30.40)	25.67±3.12 (19.10-32.10)	.137
HB (cm)	5.63±.53 (4.50-6.90)	5.88±.62 (5.00-7.10)	.131
FB (cm)	8.49±1.05 (5.80-10.30)	8.61±.73 (7.10-9.80)	.614
SR (cm)	39.64±5.21 (31.00-52.00)	38.91±5.06 (30.00-48.50)	.609
LHG (kg)	30.05±5.54 (16.00-39.00)	40.32±9.10 (27.00-66.00)	<.001**
RHG (kg)	30.18±5.75 (16.00-39.00)	42.35±9.06 (26.00-60.00)	<.001**
BS (kg)	44.87±13.07 (17.90-66.70)	65.07±12.29 (43.90-94.10)	<.001**

[Table/Fig-1]: Characteristics of the studied subjects.
Unpaired t-test. *p–value≤0.05: significant; **p–value≤0.001: highly significant. SD=Standard Deviation; VJ: Vertical Jump; WT: Body Weight; BMI: Body Mass Index; SSF: Sum of Skinfolds; HT: Standing Height; SH: Sitting Height; AS: Acromiale-Stylion Length; SD: Midstylion-Dactylion Length; TH: Trochanterion Height; AG: Relaxed Arm Girth; TG: Mid-Thigh Girth; CG: Calf Girth; AB: Biacromial Breadth; IB: Biiliocristal Breadth; HB: Biepicondylar Humerus Breadth; FB: Biepicondylar Femur Breadth; SR: Lower Back and Hamstring Flexibility; LHG: Left Hand Grip; RHG: Right Hand Grip; BS: Back Strength; n: number of players

Variables	Female (n=22)	Male (n=32)	Combined (n=54)
Age (years)	NS	.619**	NS
WT (kg)	.433*	.664**	.559**
BMI (kg/m²)	NS	NS	NS
SSF (mm)	NS	NS	-.616**
HT (cm)	NS	.739**	.761**
SH (cm)	NS	.717**	.636**
AS (cm)	NS	NS	NS
SD (cm)	NS	.399*	.599**
TH (cm)	NS	.428*	.430**
AG (cm)	NS	.573**	NS
TG (cm)	NS	.473*	NS
CG (cm)	NS	.491**	NS
AB (cm)	NS	NS	.418**
IB (cm)	NS	NS	NS
HB (cm)	NS	NS	NS
FB (cm)	NS	NS	NS
SR (cm)	NS	.446*	NS
LHG (kg)	.522*	.626**	.722**
RHG (kg)	NS	.637**	.749**
BS (kg)	NS	.711**	.712**

[Table/Fig-2]: Significantly correlated variables with VJ among the studied subjects.
Pearson's zero-order correlation (r-values given)
*p–value≤0.05: significant; **p–value≤0.001: highly significant; NS=Non-Significant.
VJ: Vertical Jump; WT: Body Weight; BMI: Body Mass Index; SSF: Sum of Skinfolds; HT: Standing Height; SH: Sitting Height; AS: Acromiale-Stylion Length; SD: Mid-Stylion-Dactylion Length; TH: Trochanterion Height; AG: Relaxed Arm Girth; TG: Mid-Thigh Girth; CG: Calf Girth; AB: Biacromial Breadth; IB: Biiliocristal Breadth; HB: Biepicondylar Humerus Breadth; FB: Biepicondylar Femur Breadth; SR: Lower Back and Hamstring Flexibility; LHG: Left Hand Grip; RHG: Right Hand Grip; BS: Back Strength

DISCUSSION

The study tried to evaluate the relations between selected anthropometric variables and VJ. Among the various anthropometric and physiological variables, TH, grip, HT, skinfold and BS were found to have major influence on VJ.

In our study, the male players, on an average, jumped higher than the females. The reason might be more strength and less body fat among the males [Table/Fig-1] [14]. Males were taller with longer sitting heights and hands; had broader chests and stronger grip and back [Table/Fig-1]. Female players, on the other hand, had longer upper arms; more skinfold thickness and bulkier thighs [Table/Fig-1]. Females are known to have more fat deposition around thighs apart from buttocks and hips as compared to males [32]. All the players had comparable age, WT, BMI, TH, AG, CG, IB, HB, FB and SR [Table/Fig-1]. They also had similar dietary and physical activity habits (not shown in the result section). Hence, difference in anthropometric parameters might be due to gender-specific post-pubertal hormonal and physiological differences [23,33].

Among the males, those who jumped higher also were older, heavier, taller with more SH; had longer hands, lower limbs; bulkier arms, thighs, calves; more flexible; and had stronger grip and back [Table/Fig-2]. Although the jumping pattern in females was suggested to be different from males with more back, hip and knee extension, and less ankle planter-flexion [20]; VJ was found to correlate significantly only with WT and LHG among females in our study [Table/Fig-2]. The gender difference might also be due to low variability among the studied females due to smaller sample size as compared to the males [20].

As contrary to ours, no significant relation of VJ with HT and WT [14,34], and with grip and BS [14] were reported earlier. Ethnicity, difference of sports and sample size might be the reason of this contrast. Our study was done on relatively younger players and the sample size was also small. However, significant positive correlation of VJ with lengths of humerus, hand, femur, tibia and foot; girths of forearm, thigh and calf; and hamstring flexibility were reported [13]. In addition, isometric muscle strength, age, height, weight [18], and level of expertise have been reported to affect VJ [13,19].

The positive correlation of VJ with WT might be related to the lean body mass and skeletal mass component of WT [14,23]. SSF correlated negatively with VJ when all the players were analysed as a whole [Table/Fig-2]. Also, among the males, one cm reduction in VJ would be expected with 7.69 mm increment in SSF after controlling for HT, BS and AS [Table/Fig-3f,g], indicating negative effect of SSF. Negative correlation between SSF and vertical jump was reported earlier [35], suggesting lower SSF to be desirable as it indicates lesser fat mass which generates no power but has to be carried vertically while jumping [10,14].

Even though no significant correlation was seen between VJ and girths among the females [Table/Fig-2], larger girths among the males might indicate more muscle cross-sectional areas and more

Studied subjects	Sl. No.	Regression equations {Durbin-Watson statistics}	Adjusted R²(%) (R²Change)	Semi-Partial correlation R²(%) for significant predictors	f-value (df)	p-value
All Players (n=54)	a^	VJ=4.03+8(G#)+.38(TH) {2.02}	55.60	G(38.44**), TH(9.06**)	29.21** (2,43)	<.001
	b^	VJ=3.44+5.5(G#)+.33(LHG)+.26(TH) {2.26}	69.00 (13.50**)	G(14.21**), LHG(13.47**), TH(4.04*)	34.40** (3,42)	<.001
	c^	VJ=1.66+4.78(G#)+.23(LHG)+.27(TH)+.08(BS) {2.22}	69.60 (1.20)	G(9**), LHG(3.39*), TH(4.49*)	26.77** (4,41)	<.001
	d^	VJ=4.10+.22(LHG)+3.23(G#)+.30(TH)+.07(BS)-.04(SSF) {2.20}	69.80 (.80)	LHG(3.20*), TH(5.06**)	21.78** (5,40)	<.001
Males (n=32)	e	VJ=-22.50+.33(HT)+.16(BS) {2.35}	58.90	HT(11.56*), BS(7.51*)	18.89** (2,23)	<.001
	f^^	VJ=-37.77+.54(HT)-.13(SSF) {1.95}	65.00	HT(57.30**), SSF(13.18**)	24.25** (2,23)	<.001
	g^^	VJ=-22.31+.38(HT)-.13(SSF)+.13(BS)+.02(AS) {2.03}	67.60 (5.00)	HT(14.67**), SSF(9.99*)	14.07** (4,21)	<.001
Females (n=22)	h	VJ=6.36+.26(LHG)+.25(TH) {2.67}	26.60	LHG(17.72*)	4.44* (2,17)	.028

[Table/Fig-3]: Regression equations for predicting VJ (cm).
Multiple Regression Analysis.
^,^^Hierarchical. *p-value≤0.05: significant; **p-value≤0.01: highly significant; df=degree of freedom. G#(Gender)=0 for male and 1 for female; VJ: Vertical Jump; SSF: Sum of Skinfolds; HT: Standing Height; AS: Acromiale-Stylion Length; TH: Trochanterion Height; LHG: Left Hand Grip; BS: Back Strength

sarcomeres, which might translate into more cross-bridges formation and force production, and hence more VJ [13]. Females, however, might have more fat deposition in their thighs as compared to males [32]. The positive association between girths and VJ among males might be coincidental finding also, and girths were not significant predictors of VJ in our study.

Although, good muscle flexibility has been thought to improve VJ as the muscle tissue may be able to accommodate the imposed stress more easily and hence move efficiently [13], there was weak positive correlation of SR with VJ only among the males [Table/Fig-2].

In our study, only TH and LHG were found to be the significant predictors of VJ after controlling gender, each other and other variables [Table/Fig-3a-d]. Among the males, however, HT, SSF and BS were predictors of VJ with significant ß-weights [Table/Fig-3e-g]. LHG was a predictor with significant ß-weight among females [Table/Fig-3h]. Even though, earlier study reported no correlation between grip strength and VJ, arm and shoulder strengths were thought to reinforce the strength in trunk and back to project maximum height jumped [14]. Hence, VJ has been reported to get affected by upper body and trunk or back strength including isometric strength [18,36]. The upper limb strength is particularly important. The arms when used while jumping to create torque in swinging, increased the torque at hip and knee joints during the propulsive phase of jumping [37], thereby, increasing the take off velocity by 6-10% or more [21,38]. Take-off velocity during a VJ was also reported to be 10% lower when the arms were restricted [21]. And, vertical jump improved by 60% with an increase in take off velocity [37].

In our studied subjects, VJ would increase by 1cm with 2.6 cm increase in TH irrespective of gender; and with 3.8 cm after additionally controlling for LHG [Table/Fig-3a,b]. This is in contrast to the earlier report that segmental skeletal length measurements like that of trunk, tibia, and femur could not predict VJ, except for foot length among males [6]. One study however, reported shank length along with maximum of calf circumference and weight as the major anthropometric parameters affecting VJ [16]. Having longer lower limb, in our case TH, may have the advantage of generating higher force for a given ground reaction and hence higher VJ, as with longer lever arm in a lever system, and higher joint torque since torque is force times the perpendicular distance from it to the axis of rotation [6,20]. Also, with the higher centre of mass, it might be easier for the player to make more force and acceleration in a longer distance of his or her body, and by means of displacement, the transmission of centre of mass would be easier in the vertical plane [13].

LIMITATION

Relatively small sample size was the limitation of the study. Other possible confounding factors for vertical jump performance were not studied like level of jumping skills, body composition, somatotyping and other anthropometric, physiological and biomechanical factors. The effect of types of sports on jump performance was also not studied. Nor any comparable non player control group was taken.

CONCLUSION

Males, on an average, jumped higher than females; and were taller with longer sitting heights; had longer hands, broader chests, stronger grip and back; shorter upper arms and less bulky thighs and skinfold thickness. VJ correlated positively with age, WT, heights including sitting and TH, segmental lengths except AS, girths, flexibility and strength variables among the males. Only WT and LHG were positive correlates among the females. TH and LHG were the significant predictors of VJ after controlling gender, each others and other variables. Among the males, however, HT, SSF and BS were significant predictors of VJ. Only LHG was significant predictor among females. The study thus provided anthropometric basis of VJ performance among the studied subjects; and it may not only help in training-monitoring and players' selection, but also form the basis of future well designed study in this field.

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PARTICULARS OF CONTRIBUTORS:

1. Senior Resident, Department of Physiology, Maulana Azad Medical College, New Delhi, India.
2. Assistant Professor, Department of Physiology, K.D. Medical College Hospital and Research Centre, Mathura, Uttar Pradesh, India.
3. In-charge, Sports Sciences and Fitness Centre, NERC-SAI, Imphal, Manipur, India.
4. Professor, Department of Physiology, HIMS, SRHU, Dehradun, Uttarakhand, India.
5. Professor, Department of Plastic Surgery, HIMS, SRHU, Dehradun, Uttarakhand, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Hanjabam Barun Sharma,
Wangkhei-Khunou, Imphal-East-795001, Manipur, India.
E-mail: dr.barun.hanjabam@gmail.com

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