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ASSOCIATION OF ANTHROPOMETRIC CHARACTERISTICS AND BODY COMPOSITION WITH THE PERFORMANCE AMONG MALE SOFTBALL PLAYERS

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Abstract:
The purpose of this study was to determine relationship of anthropometric parameters with performance among softball players and to find the anthropometric predictors of performance in softball. Total 150 male softball players from the various states and universities of India were selected to participate in the study. Height and length measurements of the players were measured with the anthropometric rod. Portable weighing machine was used to measure the weight of the players. Circumferences and diameters of the body parts of the players were measured with steel tape and sliding caliper respectively. Harpenden skinfold caliper was used to assess the skinfold thicknesses. The results revealed that the height ($p=0.010$), weight ($p=0.001$), total arm, upper arm and lower arm lengths ($p<0.05$); Upper arm, forearm, chest and calf circumferences ($p<0.05$); biacromial, bicondylar humerus and bicondylar femur diameters ($p<0.05$) and lean body mass ($p=0.000$) were significantly associated with performance among softball players. Regression analyses showed that for softball performance, 13% variance was accounted for by lean body mass, 3% was explained by upper arm circumference, and an additional 3% of the variance was explained by upper arm length. It is concluded that lean body mass was the prime predictor of the softball performance.

Keywords: anthropometric measurements, performance, percent body fat, lean body mass, softball

1. Introduction

Softball has endured resurgence in popularity in the recent years and has emerged both as a recreational and competitive team sport. The game of softball was first developed as an indoor game by George Hancock in 1887 in Chicago and was turned into an

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outdoor game at Minneapolis, Minnesota by Lewis Rober Sr. in 1895 (www.isfsoftball.org/English/the_isf/history_of_softball.asp). The term 'softball' was first used in 1926 by Walter Hakanson, an official of the Young Men's Christian Association (YMCA) of Denver, Colorado (http://www.isfsoftball. org). Softball is an Olympic sport and is played in many countries, especially in Latin America (Cuba), Europe, China and Japan. In India, softball was played for the first time in Rajasthan. Dr. Dashrath Mal Mehta, the father of Indian softball, formed the Softball Association of India on Nov 21, 1961. The International Softball Federation was formed in 1964 in America. The first World Softball Championship (women) was organized in Australia in 1965 by the International Softball Federation. After the federation team visited India, the first rule book on softball game was published in India in 1965 to promote softball game in different states. In the year 1967 first national softball championship for men and women was organized at Jodhpur. All India council of sports recognized the Softball Association of India in 1973. (http://www.softballindia.com/history.php).

Softball is a baseball descendant game that requires speed, strength, and endurance. Apart from this, softball game requires the basic physical structural composition of the players which suits best to the demands of the sport and a particular playing position for higher performance. Anthropometry, a quantitative interface between anatomy and physiology, provides appraisal of an individual's structural status as well as provides quantification for different growth and training influences.[1] There have been reports on investigations on the relationships between anthropometric and physical performance parameters and sport performance. Chen[2] examined the influence of anthropometric characteristics and physical performance on the competition results and suggested that anthropometric characteristics and physical performance are closely correlated to each other. Anthropometry helps the sport scientists to identify the anthropometric characteristics to predict the performance. Requirement of sport-specific physique for superior performance in sports had been reported by different studies.[3]

The importance of evaluating sport-specific skills, as well as anthropometric and physiological characteristics in different sports, is vital to understand sport performance, as high anthropometric and physical fitness qualities improve playing performance.[4,5] These anthropometric and morphological characteristics are the significant predictors of physical growth and nutritional status of the sportspersons for their maximal performances.[6,7] These predictors of perspective sports performance depend largely on age, gender, genetics, ethnicity, altitude, socio-economic status, nutritional status, personal hygiene and exercise practice.[7,8] Proper evaluation of these factors depicts the quantification of anthropometric characteristics of elite players which can be very important in associating body structure and performance in sports.[7,9] Performances and skills, body dimensions and proportions, and exercise physiological attributes constitute a very important part of selecting and educating the sports persons.[10] Physical characteristics have a remarkable effect on the performance level of a player besides personal skill and mental ability. A large number of studies had been

reported on players about their morphological assessment along with their performance related morphological issues.[11,12,13] Anthropometric measurements in relation to performance has also been reported in different sports viz. basketball players [14,15,16], volleyball players from colleges and universities of North India [17], national level athletes from Bangladesh institute of sports [3], wrestlers from Colombia[18], Indian elite male hockey players[19], track and field athletes[20,21], volleyball players[4,22], baseball players[23,24,25,26], softball players[27,28,29], water sports athletes [30,31], football players[32,33], handball players [34,35,36] and gymnastic players.[37]

Body composition on the other hand refers to the distribution of muscle and fat in the body. Assessment of anthropometric parameters and body composition, therefore, has an important role in sports and health. Excess body fat besides leading to obesity and disease causation, may also hinder performance.[1] The association of body composition with physical performance changes is also of great interest to strength and conditioning specialists.[38] Body composition of athletes is also an essential tool to evaluate the health of the athletes, observe the effects of a training program, and to find out most favorable competitive body weight and body composition.[39] It is generally accepted that a lower relative body fat is required to succeed in competition in most of the sports. This is due to the fact that excess body fat acts as a dead weight in activities where the body mass must be repeatedly raised against gravity during locomotion.[40]

Anthropometric characteristics and body composition components are an essential part of the evaluation and selection of players for different sports, standard data on such factors are still scant in the Indian context on softball players. There is also very scant information regarding the anthropometric characteristics as the predictors of performance in softball. The present study, therefore, aimed at evaluating the anthropometric measurements and body composition and to assess their association (if any) with the performance in softball players from India.

2. Methodology

The subjects of the present study were purposively selected from the university level and national level male softball players. 150 male softball players (mean age: 21.35±2.57 years) of different universities and states of India were selected to participate in the study. The data for the study was collected during the 33rd Senior National Softball Championship held at Anantpur District of Andhra Pradesh in January, 2012 and All India Inter University Softball Championship held at Panjab University, Chandigarh in February 2012.

2.1 Anthropometry

The age of each player was calculated from the date of birth as recorded in their institutes. The height of the players was measured with anthropometric rod to the nearest 0.5 cm (HG- 72, Nexgen ergonomics, Canada). Portable weighing machine was used to measure the weight of the softball players to the nearest 0.5 kg. Circumferences

of the body parts of the players were measured with the steel tape. Diameters of the body parts of the players were assessed with the digital sliding caliper. Harpenden skinfold caliper was used to assess the skinfold thicknesses of the players.

2.2 Body Mass Index

Body mass index (BMI) of the softball players was calculated with the help of following formulae

BMI (Kg/m^2) = (Body Weight in Kg) / (Body Height in Meters)^2

(Meltzer *et al.*, 1988)

2.3 Body Composition

Percentage body fat as estimated from the sum of skinfolds was calculated using equations of Siri (1956) and Durnin and Womersley (1974). The regression equations for the prediction of body density from the log of the sum of skinfold thickness at four sites in mm are as follows:

For Males	
17 to 19 years age group **Body Density (gm/cc) = 1.1620-0.0630 (X)**	**20 to 29 years age group:** **Body Density (gm/cc) = 1.1631-0.0632 (X)**

Where:
X = log (biceps+triceps+Subscapular+suprailliac).
Percent Body Fat = [4.95/ body density-4.5] × 100, (Siri, 1956)
Total Body Fat (kg) = (%body fat/100) × body mass (kg)
Lean Body Mass (kg) = body mass (kg) – total body fat (kg)

2.4 Softball Performance

Softball performance of the players was assessed by AAHPERD softball skill test battery edited by Dr. Roberta Rikli (AAHPERD, 1991). This test battery was based on the measurement of skills essential for softball performance namely batting, fielding, throwing and base running. Accordingly, this test has following four items:

1. Batting Test;
2. Fielding Ground Balls Test;
3. Throwing Test;
4. Base Running Test.

2.5 Batting Test

This test item assesses power and placement in softball. Based on the concurrent validity calculated from the relationship between test scores and experts skill ratings, validity coefficient ranged from 0.54 to 0.85. Reliability coefficient is found to be 0.69 to 0.91 as calculated from the intra-class test-retest scores' coefficient of correlation. For this test, the softball field was designed as shown in fig. 1. Three power zones were created at a distance of 60', 180' and 240' away from the batting site. The softball was placed on a batting tee (adjustable to a proper height) and the subject was required to

hit the ball as long and as straight as possible. Each subject was given six trials. The score to the batted ball was assigned as per the landing zones scores shown in the fig. 1. The sum of the six balls was the final score.

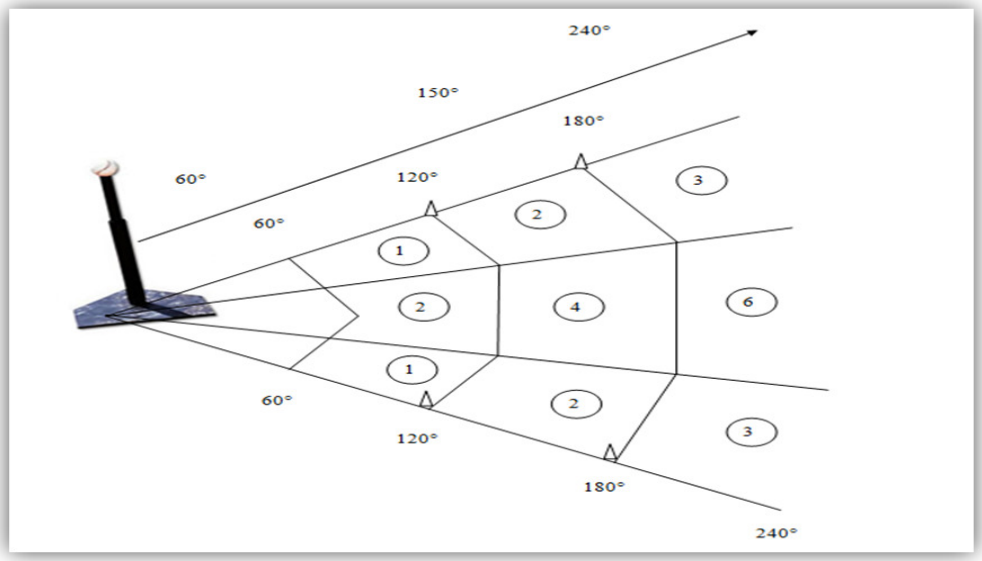

Figure 1: Field marking for batting test

2.6 Fielding Ground Balls Test

This test item assesses the fielding ground ball ability of the subject. Validity coefficient of correlation has been found to range from 0.60 to 0.85. Reliability coefficient of correlation ranged from 0.69 to 0.91 from the intra-class test-retest scores. For this test, the area was marked as shown in fig. 2. The subject stood behind the restraining line (Point A). A thrower (Point B) stood behind the throwing line and throws six test balls to each subject. Each throw must strike the ground before the 30-feet line and must stay within the sideline boundaries of the marked area. The throws were sidearm, with sufficient velocity to carry an untouched ball beyond the end line (Point C). Of the six test trials, two balls (in varying order) were thrown directly to the subject, two to the right and two to the left side of the subject. Each ball cleanly fielded in front of the 60-feet line was count 4 points. A ball counted 2 points when it was stopped, but bubbled. Balls fielded behind the 60-foot line received one-half the points normally earned. Balls that get past the subject scored no points. The final score was the sum of six trials.

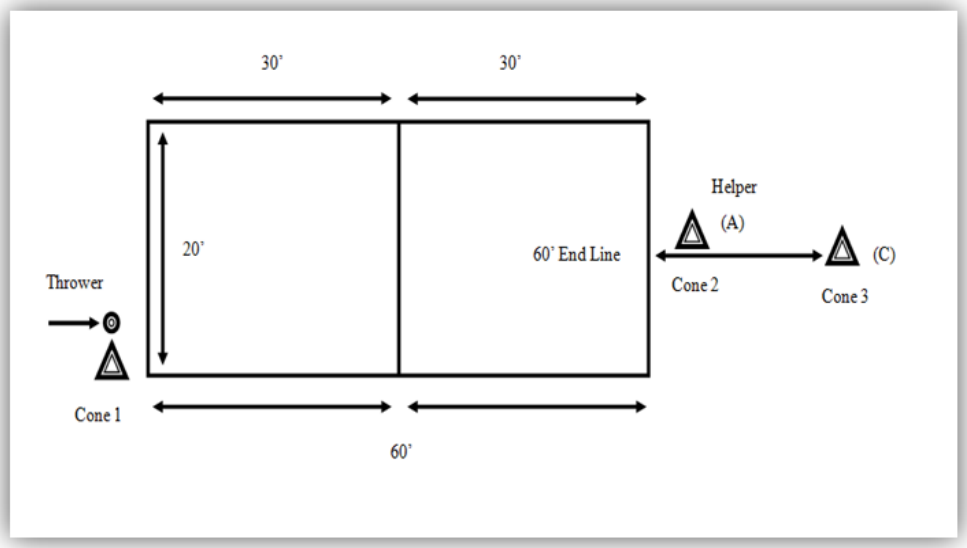

Figure 2: Field marking for fielding ground balls test

2.7 Throwing Test

This test assesses the skill in the overhand ball throw by measuring distance and placement of ball. Concurrent validity has been reported by finding the correlation coefficient between the test scores and judges' rating. The validity correlation coefficient ranged from 0.64 to 0.94. The test-retest reliability coefficient from intra-class repeated scores ranged from 0.90 to 0.97. For this test, a perpendicular line was marked from a restraining line as shown in fig. 3. In this test, the subject was required to throw the ball as far and as straight as possible, along the throwing line. The ball was released after taking few steps and released before the restraining line. Each subject was given two trials. The better of two trials was the final score.

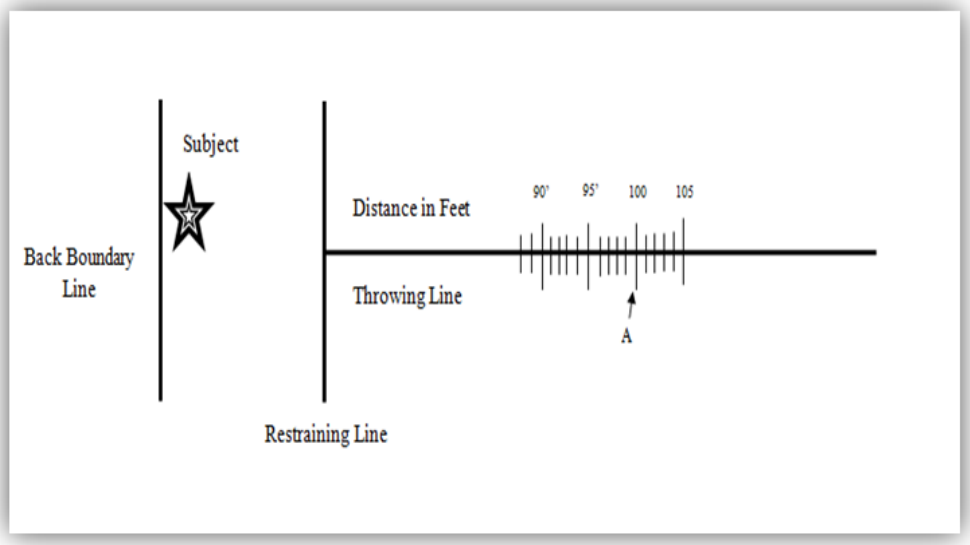

Figure 3: Field marking for overhand throwing test

2.8 Base Running Test

This test item assesses the subject's skill in base running with the help of measuring the speed in running two bases. The concurrent coefficient reported ranged from 0.79 to 0.92. The test-retest reliability coefficient from intra-class repeated scores ranged from 0.89 to 0.95. For this test, the softball field was prepared as indicated in fig. 4. The subject was asked to take the start from the 'S' position and run as fast as possible from point S to around first base to second base. Each subject was allowed two test trials. The timer standing at point B2 started the stop watch with the signal go when the subject started the run, the timer moved to position B1 and stopped the stop watch as soon as the subject reached the second base. The best i.e. faster of two, recording lesser time was taken as the final score of the test item.

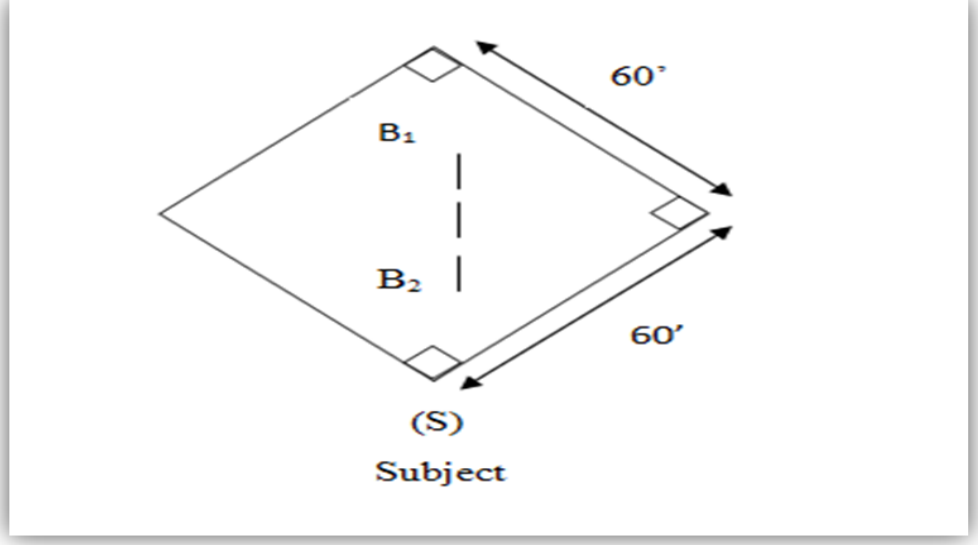

Figure 4: Field marking for base running test

2.8 Statistical Analyses

Statistical analyses were performed using SPSS version 16.0 for windows (SPSS Inc, Chicago, IL, USA). The data was presented as descriptive statistics such as mean, standard deviation, 95% CI, Skewness, Kurtosis etc. The scores of the softball skill test items i.e. batting test, fielding ground balls test, throwing test and base running test were converted into standardized T-scores and then added to make composite score of softball performance. Karl Pearson's product moment co-efficient of correlation was computed to assess the relationship of anthropometric parameters with performance among the softball players. To predict the performance among softball players from anthropometric parameters, stepwise regression analyses were applied. Significance levels were set at $p<0.05$.

3. Results

Table 1: Descriptive statistics of anthropometric parameters of the male softball players

Variables	Mean	SD	95% Confidence Interval for Mean		Skewness	Kurtosis
			Upper Bound	Lower Bound		
Age (yrs)	21.25	2.66	20.77	21.73	1.73	4.60
Height (cm)	172.84	6.39	171.69	173.99	-0.33	-0.08
Weight (kg)	65.58	9.06	63.95	67.21	0.33	0.01
Body Mass Index (kg/m^2)	21.95	2.88	21.43	22.47	1.07	1.16
Total Arm Length (cm)	77.31	3.12	76.75	77.88	-0.19	0.18
Upper Arm Length (cm)	31.58	1.87	31.24	31.92	-1.29	3.63
Lower Arm Length (cm)	45.74	2.27	45.33	46.14	0.96	4.45
Total Leg Length (cm)	95.33	5.65	94.31	96.35	0.07	-1.03
Upper Leg Length (cm)	44.75	4.34	43.97	45.53	0.23	-1.14
Lower Leg Length (cm)	50.58	2.40	50.15	51.01	-0.56	0.67
Upper Arm Circumference (cm)	25.98	2.87	25.47	26.50	0.03	-0.38
Forearm Circumference (cm)	24.38	2.01	24.01	24.74	-0.08	-0.82
Chest Circumference (cm)	87.54	6.70	86.33	88.74	0.12	-0.18
Thigh Circumference (cm)	53.07	4.56	52.24	53.89	-0.65	-0.10
Calf Circumference (cm)	33.45	2.69	32.97	33.94	0.26	0.35
Biacromial Diameter (cm)	41.90	2.06	41.53	42.27	0.48	-0.10
Bicondylar Humerus Diameter (cm)	6.63	0.37	6.57	6.70	0.04	0.30
Wrist Diameter (cm)	5.38	0.28	5.33	5.43	-0.08	-0.11
Bicondylar Femur Diameter (cm)	9.72	0.49	9.63	9.81	-0.16	-0.45
Biceps (mm)	5.59	2.12	5.20	5.97	0.82	1.17
Triceps (mm)	10.52	4.02	9.79	11.24	0.80	1.67
Subscapular (mm)	13.88	6.14	12.78	14.99	1.21	1.77
Supra-iliac (mm)	13.44	6.91	12.20	14.69	0.86	1.12
Calf (mm)	10.27	3.50	9.64	10.90	0.57	0.40
Percent Body Fat (%)	16.23	5.10	15.31	17.14	-0.15	-0.57
Total Body Fat (kg)	10.93	4.45	10.13	11.73	0.37	-0.10
Lean Body Mass (kg)	54.65	5.96	53.58	55.72	0.01	-0.36

Descriptive statistics of the anthropometric parameters of the softball players is presented in table 1. The table 2 presents the correlation analyses of anthropometric characteristics with the softball performance among the male softball players. The results of correlation analyses revealed a significant positive association of height (r=0.210, p=0.010) with the softball performance. The weight of softball players also showed a significant relationship (r=0.266, p=0.001) with the performance. The age and body mass index of the male softball players did not show significant association with the softball performance. The results of correlation analyses revealed a significant association of softball performance with the total arm (r=0.267, p=0.001), upper arm (r=0.228, p=0.005) and lower arm lengths (r=0.1844, p=0.024) among the male softball players. Whereas, the total leg, upper leg and lower leg lengths did not show significant relationship with the softball performance among the male softball players. The softball performance was observed to be significantly associated to upper arm circumference (r=0.280, p=0.001), forearm circumference (r=0.294, p=0.000) and the chest circumference (r=0.212, p=0.009) among the male softball players. Similarly, the calf circumference

demonstrated significant relationship (r=0.161, p=0.049) with the softball performance among the male softball players. However, the thigh circumference showed no significant association with the softball performance. The biacromial (r=0.212, p=0.009), the bicondylar humerus (r=0.279, p=0.001) and bicondylar femur (r=0.162, p=0.048) diameters were observed to be significantly associated to softball performance among male softball players. However, the wrist diameter did not demonstrate significant relationship with softball performance among the male softball players. However, no significant association of the skinfold thicknesses of the body parts viz. biceps, triceps, subscapular, supra-iliac and calf with the softball performance was observed among the male softball players. Among the body composition components, only lean body mass (r=0.370, p=0.000) was observed to be significantly associated to the softball performance among the male softball players. However, the performance did not demonstrate significant association with percent body fat and total body fat among the male softball players.

Table 2: Relationship of anthropometric parameters with the performance in male softball players

Variables	N	Pearson Correlation Coefficient (r)	p-value
Age (yrs)	150	0.148	0.070
Height (cm)	150	0.210	0.010*
Weight (kg)	150	0.266	0.001*
Body Mass Index (kg/m^2)	150	0.160	0.050
Total Arm Length (cm)	150	0.267	0.001*
Upper Arm Length (cm)	150	0.228	0.005*
Lower Arm Length (cm)	150	0.184	0.024*
Total Leg Length (cm)	150	0.122	0.138
Upper Leg Length (cm)	150	0.124	0.129
Lower Leg Length (cm)	150	0.061	0.455
Upper Arm Circumference (cm)	150	0.280	0.001*
Forearm Circumference (cm)	150	0.294	0.000*
Chest Circumference (cm)	150	0.212	0.009*
Thigh Circumference (cm)	150	0.020	0.813
Calf Circumference (cm)	150	0.161	0.049*
Biacromial Diameter (cm)	150	0.212	0.009*
Bicondylar Humerus Diameter (cm)	150	0.279	0.001*
Wrist Diameter (cm)	150	0.048	0.556
Bicondylar Femur Diameter (cm)	150	0.162	0.048*
Biceps (mm)	150	-0.108	0.190
Triceps (mm)	150	-0.078	0.346
Subscapular (mm)	150	-0.082	0.316
Supra-iliac (mm)	150	-0.095	0.246
Calf (mm)	150	-0.030	0.717
Percent Body Fat (%)	150	-0.093	0.256
Total Body Fat (kg)	150	0.036	0.664
Lean Body Mass (kg)	150	0.370	0.000*

* Indicates p<0.05

2.9 Anthropometric predictors of performance in male softball players

The scores obtained from the various anthropometric parameters were correlated with the performance score using the step-wise regression technique.

Table 3: Summary of regression prediction of softball playing ability with anthropometric parameters

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.370[a]	0.137	0.131	28.02756
2	0.412[b]	0.17	0.158	27.58165
3	0.451[c]	0.203	0.187	27.10397
4	0.485[d]	0.235	0.214	26.655

a. Predictors: (Constant), Lean body mass
b. Predictors: (Constant), Lean body mass, Thigh circumference
c. Predictors: (Constant), Lean body mass, Thigh circumference, Upper arm circumference
d. Predictors: (Constant), Lean body mass, Thigh circumference, Upper arm circumference, Upper arm length

Table 4: Coefficients[a] of regression prediction of softball performance with anthropometric parameters

Model	Unstandardized Coefficients		Standardized Coefficients	t-value	sig.
	B	Std. Error	Beta		
1 (Constant)	92.645	22.330		4.149	0.000
Lean Body Mass	1.971	0.407	0.370	4.839	0.000
2 (Constant)	140.070	29.480		4.751	0.000
Lean body mass	2.505	0.458	0.470	5.472	0.000
Thigh circumference	-1.427	0.591	-0.207	-2.413	0.017
3 (Constant)	138.644	28.975		4.785	0.000
Lean body mass	1.986	0.496	0.372	4.007	0.000
Thigh circumference	-2.189	0.657	-0.318	-3.335	0.001
Upper arm circumference	2.716	1.088	0.257	2.495	0.014
4 (Constant)	69.736	40.109		1.739	0.000
Lean body mass	1.787	0.494	0.335	3.617	0.000
Thigh circumference	-2.692	0.678	-0.391	-3.933	0.000
Upper arm circumference	2.744	1.070	0.260	2.564	0.011
Upper arm length	3.347	1.371	0.201	2.441	0.016

a. Dependent variable: softball performance

The anthropometric predictors of softball performance were entered into a stepwise regression model. Using the stepwise method, a significant model emerged ($F_{4,145}$ =11.132, P<0.0001) as shown in tables 3 and 4. Adjusted R square value is 0.214 which tells that model accounts for 21% of variance in the softball performance. For softball performance, 13% of the variance was accounted for by lean body mass, 2% was explained by thigh circumference, 3% was explained by upper arm circumference and an additional 3% of the variance was explained by the upper arm length. The regression equation for softball performance on the basis of anthropometric parameters is as following

Softball performance = 69.736 + 0.335 x (lean body mass) - 0.391 x (thigh circumference) x + 0.260 x (upper arm circumference) + 0.201 x (upper arm length)

3. Discussion

The present study evaluated the anthropometric parameters and body composition of the male softball players and also assessed their association with the performance in softball players. The height of the male softball players in the present study was comparable with the height of the university level softball players studied by Koley and Kumaar [45], university level baseball players studied by Dhaliwal and Singh [46], collegiate softball players from Thailand [47] and Japanese high school and university level baseball players.[48,49] The male softball players were shorter than the Indian college level softball and baseball players studied by Singh and Gaurav [50], baseball players from minor and major baseball league reported by Hoffman *et al.*[23], Cuban baseball players studied by Carvajal *et al*.[51], Korean elite baseball players [52] and high school, college and university level baseball players from USA[53,24,54]. The male softball players in the present study were found to have similar weight with that of university level male softball players studied by Koley and Kumar [45], collegiate softball players from Thailand [47] and Japanese high school and university level baseball players.[48,49] On the other hand, the softball players in the present study were lighter than the Indian college level softball and baseball players [50], university level baseball players [46], minor and major baseball league players, high school, college, university level and professional baseball players from USA [53,23,24,54,55], Korean elite baseball players [52] and Cuban baseball players.[51] Body mass index of male softball players was comparable with the body mass index of previously studied Indian college level softball and baseball players, university level male softball players [45,50] and Japanese high school baseball players.[48] The length measurements of upper limb (total arm, upper arm and lower arm length) of the male softball players in the present study were comparable to the state level softball players studied by Bhagat *et al*. [56] but were shorter than those of Indian university level baseball players studied by Dhaliwal and Singh [46] and Cuban baseball players investigated by Carvajal *et al*.[51]. The male softball players had greater lower limb measurements (total leg, upper leg and lower leg length) than the state level softball players studied by Bhagat *et al*. [56] but were shorter than those of Indian university level baseball players studied by Dhaliwal and Singh [46] and Cuban baseball players investigated by Carvajal *et al*.[51]. The circumferences and diameters of body parts on the softball players were evaluated as these parameters depict the growth and development of an individual. The male players had lower upper arm, forearm and chest circumferences in comparison to Indian university level baseball players studied by Dhaliwal and Singh [46], NCAA Division II college baseball players [53] and lower chest circumference than the Korean elite baseball players.[52] The male softball players also had lower body diameters (biacromial and wrist) in comparison to Cuban baseball players reported by Carvajal *et al*.[51].

The percent body fat of the male softball players was within the normal limits and was higher than the under-15 Indian softball players studied by Rao and Kumar [57],

minor and major baseball league players reported by Hoffman *et al*.[23], high school and professional baseball players from USA [24,55], NCAA Division II baseball players [53], Japanese high school baseball players [48] and elite Korean baseball players.[52] On the other hand, the male softball players in the present study had lesser fat percentage than the Cuban baseball players [51] and collegiate softball players from Thailand.[47] The male softball players had lesser lean body mass in comparison to the minor and major baseball league players [23], Cuban baseball players [51], high school and professional baseball players from USA [24,55], NCAA Division II baseball players [53] and Japanese high school baseball players.[48]

The scores of various skills (batting, fielding, throwing and base running) were converted into standardized scores and then these standardized scores were added to obtain composite score for performance among the softball players. The relationship of softball performance with the anthropometric parameters was evaluated. The height and weight showed a significant association with the performance among the male softball players. These findings are in agreement with other studies which investigated high school and professional baseball players [24,25], youth baseball players [26], collegiate female softball players.[58,27,28] However, the results of the present study are not in line with those reported by Hoffman *et al*. [23] on professional baseball players showing no relationship of height and weight with the baseball specific performance. The association of height with the softball performance showed that it is advantageous to have greater height in softball to achieve higher performance. Height provides mechanical advantage in performing various skills of softball such as pitching, throwing, catching, hitting, running etc. The higher body weight is also advantageous in performing different skills in softball as the players require greater strength to hit the ball for longer distance and throw the ball further and the strength is relative to body mass.[59] Higher body weight provides the softball players an advantage in gaining high momentum while transferring body weight from back foot to the front foot during swinging phase in hitting to execute longer and powerful hits.

The findings of present study reported a significant association between total arm, upper arm and lower arm lengths with the performance among male softball players. The height and longer upper and lower limbs in softball players provide mechanical advantage as due to the longer bones, longer levers are capable of producing more work.[60,61,62] The longer upper and lower limbs provide advantage in skills such as hitting, throwing, fielding, catching and pitching as these increases the range of a player. The circumferences of body parts (forearm, upper arm, calf and chest) of the softball players showed a positive significant relationship with performance among softball players. The circumference of a body segment is used as an indication of muscle mass cross sectional area [6] and consequently of higher power and force output for these segments. Human muscular power is determined by muscle fibre type, muscle strength and muscle mass.[63,64] Therefore, the greater development of these areas is greatly helpful for skills such as hitting and throwing. The diameters of body parts (biacromial, bicondylar humerus and bicondylar femur) of the softball players had

positive significant association with the performance. The higher diameters of body parts may indicate the better growth and development of the softball players. The higher growth and development of arm and shoulder region is indispensable for greater strength in the upper limbs which is important factor for higher performance among softball players.

The skinfold thicknesses and percent body fat did not reveal a significant association with performance among male softball players. An increased fat weight will be detrimental for performance in softball because the body is moved against the gravity (e.g. fielding, catching the ball) or propelled horizontally (moving around during fielding and base running etc.) as the additional body fat adds to the weight of the body without contributing to its force production or energy producing capabilities.[65] The findings of the present study are in agreement with those reported on minor and major baseball league players by Hoffman *et al*. [23] and under-15 softball players studied by Rao and Kumar.[57] On the other hand, these findings are in contrast to those reported by Lowe *et al*. [27] and Till *et al*. [58] on NCAA Division I female softball players showing significant relationship between body fat and softball specific performance. Mangine *et al*.[25] also reported a significant relationship between body fat and performance in the professional baseball players. The lean body mass demonstrated a significant correlation with performance among male softball players. Many studies are in agreement with the findings of current study such as reported on the minor and major baseball league players [23], NCAA Division I female softball players [27] and professional baseball players.[25] The greater muscular development of the softball players would provide them an advantage in hitting and throwing the ball, at the same time the greater lean body mass would imply economy in moving body mass for fielding the ball and in running around the bases.[66] Many research studies reported that the lean body mass have better association to success in sport as it enables the muscles to generate greater energy and power [67,68,69] and functional efficiency.[70]

The anthropometric model for male players accounts for 21% of variance in the softball performance. Lean body mass was the prime predictor of softball performance as it accounts for 13% of the variance. Thigh and upper arm circumferences and upper arm length were the other significantly contributing variables in the softball performance. These findings are not in agreement with those reported by the Hoffman *et al*.[23] on the professional baseball players. They reported that the anthropometric characteristics did not contribute significantly to the baseball specific performance. Nakata *et al*.[26] examined the relationship of anthropometric and performance parameters with the baseball ability among the youth baseball players. They reported that the body mass index as one of the predictors of the hit ball kinetic energy. The results of the present study are not in conformity with those reported by Szymanski *et al*. [24] on high-school baseball players. They studied the relationship of anthropometric and physiological variables with the bat swing velocity and found no significant contributions of anthropometric characteristics in the baseball performance. Till *et al*.[58] determined the relationship of performance variables with bat swing and throwing

velocity of the female college softball players. They found that the body mass and percent body fat were associated with bat swing velocity whereas height was associated with the throwing velocity. Similarly, Wentzel and Travil [29] examined the softball players from South Africa and found that the height and percent body fat were significantly associated with the batting and base running performance.

It is concluded from the above discussion that there was significant variation in contribution of different anthropometric characteristics in the softball playing ability among male players.

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