


Anthropometric and physiological characteristics on Indian inter-university volleyball players

SHYAMAL KOLEY , JARNAIL SINGH, JASPAL SINGH SANDHU

Department of Sports medicine and physiotherapy, Guru Nanak Dev University, India.

ABSTRACT

Koley S, Singh J, Sandhu JS. Anthropometric and physiological characteristics on Indian inter-university volleyball players. *J. Hum. Sport Exerc.* Vol. 5, No. 3, pp. 389-399, 2010. The purpose of this study was of two-folds, firstly, to evaluate the anthropometric profile of Indian inter-university volleyball players and, secondly, to search the correlation of body mass index, % body fat, hand grip strength (right dominant) and Vo_2max . with other anthropometric characteristics studied. Eleven anthropometric characteristics, four body composition parameters, two physical and two physiological variables and nine arm anthropometric characteristics were measured on randomly selected 63 inter-university Indian volleyball players (38 males and 25 females) aged 18–25 years from Guru Nanak Dev University, Amritsar, Punjab, India with adequate controls ($n = 102$, 52 males and 50 females). The results indicated that male volleyball players were taller (6.63%) and heavier (7.31%) and female volleyball players were slightly taller (0.31%) and lighter (3.74%) than their control counterparts. One way analysis of variance showed significant ($p \leq 0.004-0.000$) between group differences in all the variables (except hip circumference) between volleyball players and controls. In volley players, significantly positive correlations were found with BMI and other 19 variables, with percent body fat and 6 variables, with right hand grip strength and 20 variables and with Vo_2max and other 19 variables, and significantly negative correlations were found with percent body fat and other 16 variables, with right hand grip strength and other 7 variables and with Vo_2max with other 8 variables. The findings of the present study might be useful in future investigation on player selection, talent identification in volleyball and training program development. **Key words:** ANTHROPOMETRIC CHARACTERISTICS, HAND GRIP STRENGTH, VO_2MAX , INDIAN INTER-UNIVERSITY VOLLEYBALL PLAYERS.

 **Corresponding author.** Department of Sports Medicine and Physiotherapy, Guru Nanak Dev University, Amritsar – 143005, Punjab, India.
Phone: +91 0183 2258802-09, Ext. 3338; Fax: +91 0183-2258820
E-mail: drkoley@yahoo.co.uk
Submitted for publication March 2010.
Accepted for publication July 2010.
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202
© Faculty of Education. University of Alicante
doi:10.4100/jhse.2010.53.09

INTRODUCTION

Anthropometric dimensions and morphological characteristics play an important role in determining the success of an athlete (Rico-Sanz, 1998; Wilmore & Costill, 1999; Keogh, 1999). Quite naturally, the interest in anthropometric characteristics and body composition of sportspersons from different competitive sports has increased tremendously over the last decades. It has been well established that specific physical characteristics or anthropometric profiles indicate whether the player would be suitable for the competition at the highest level in a specific sport (Claessens, Lefevre, Beunen, & Malina, 1999; Bourgois et al., 2000; Reilly, Bangsbo, & Franks, 2000; Gabbett, 2000; Ackland, Ong, Kerr, & Ridge, 2003; Slater et al., 2005). These anthropometric and morphological parameters are the sensitive indicators of physical growth and nutritional status of the sportspersons for their maximal performances (Wilmore & Costill, 1999; Chatterjee, Chatterjee, & Bandhyopadhyay, 2006). These indicators of perspective sports performance depend largely on genetics, correlated with age, sex, socio-economic status, ethnicity, altitude, nutritional status, personal hygiene and exercise practice (Bouchard & Lortie, 1984; Fagard, Bielen, & Amery, 1991). Proper evaluation of these parameters projects the quantification of morphological characteristics of elite athletes which can be vital in relating body structure and sports performance (McArdle, Katch, & Katch, 2001).

Several studies have examined the relationships between anthropometric and physiological characteristics of volleyball players (Gladden & Colacino, 1978; Morrow, Jackson, Hosler, & Kachurik, 1979; Kovaleski, Parr, Hornak, & Roitman, 1980; Spence, Disch, Fred, & Coleman, 1980; Fleck, Case, Puhl, & Van-Handle, 1985; Fry et al., 1991). The findings of these studies have shown that certain anthropometric characteristics are advantageous to the volleyball players, including greater height (Gladden & Colacino, 1978; Spence, Disch, Fred, Coleman, 1980), greater vertical jump distance (Gladden & Colacino, 1978; Fleck, Case, Puhl, & Van-Handle, 1985), greater mass (Kovaleski, Parr, Hornak, & Roitman, 1980; Spence, Disch, Fred, & Coleman, 1980), greater upper body strength (Pedegana et al., 1982; Fry et al., 1991) and lower body fat percent (Morrow, Jackson, Hosler, & Kachurik, 1979; Fleck, Case, Puhl, & Van-Handle, 1985).

In spite of the availability of the literature related to anthropometric and morphological parameters in volleyball players, standard data on such parameters are scanty in Indian context. To fulfill the lacunae of literature, the present study was planned.

MATERIAL AND METHODS

Participants

The present cross-sectional study is based on randomly selected 63 inter-university Indian volleyball players (38 males and 25 females) aged 18–25 years (mean 19.05 ± 1.40 years) from six Indian universities and the competition was held in Guru Nanak Dev. An adequate number of controls ($n = 102$, 52 males and 50 females, mean age 21.60 ± 2.13 years) with no particular athletic background were also collected from the same place for comparisons. The age of the subjects were recorded from the date of birth registered in their respective institutes. The subjects were divided in such a way that age 18 refers to the individuals aged 17 years and 6 months through 18 years and 5 months and 29 days. A written consent was obtained from the subjects. The data were collected under natural environmental conditions in morning (between 8 AM. to 12 noon). The study was approved by the local ethical committee.

Measurements and calculations

Eleven anthropometric variables, viz. height, weight, BMI, chest circumference, hip circumference, femur biepicondylar diameter, humerus biepicondylar diameter, biceps skinfold, triceps skinfold, subscapular skinfold and calf skinfold, four body composition parameters, viz. percent body fat, percent lean body mass, basal metabolic rate and water percent, two physical parameters, viz. right and left hand grip strength and two physiological variables, viz. heart rate and $VO_2\text{max}$ were taken on each subject. Nine arm anthropometric variables, viz. upper arm length, lower arm length, total arm length, upper arm circumference, arm muscle area, arm area, arm fat area and arm fat index were measured on each subject. Anthropometric variables of the subjects were measured using the techniques provided by Lohmann, Roche, and Martorell (1988) and were measured in triplicate with the median value used as the criterion.

The height was recorded during inspiration using a stadiometer (Holtain Ltd., Crymych, and Dyfed, UK) to the nearest 0.1 cm, and weight was measured by digital standing scales (Model DS-410, Seiko, Tokyo, Japan) to the nearest 0.1 kg. BMI was then calculated using the formula $\text{weight (kg)}/\text{height}^2(\text{m})^2$. Chest, hip and upper arm circumferences were measured by a flexible metallic tape (Holtain Ltd). Femur and humerus biepicondylar diameters, upper arm length, forearm length and total arm length were measured by sliding calliper and anthropometer. Percent body fat was assessed using skinfold measurements taken from four sites, viz. biceps, triceps, subscapular and calf using Harpenden skinfold caliper (Holtain Ltd, Crosswell, Crymych, UK) to the nearest 0.2 mm, and using the Durnin and Womersley (1974) skinfold equation. Percent lean body mass was calculated subtracting percent body fat from 100. Basal metabolic rate and water percent were assessed by Bioelectrical Impedance Analysis (Houtkooper et al., 1996). The grip strength of both right and left hands was measured using a standard adjustable digital handgrip dynamometer (Takei Scientific Instruments Co., LTD, Japan) at standing position with shoulder adducted and neutrally rotated and elbow in full extension. The dynamometer was held freely without support, not touching the subject's trunk. The position of the hand remained constant without the downward direction. The subjects were asked to put maximum force on the dynamometer thrice from both sides of the hands. The maximum value was recorded in kilograms. All subjects were tested after 3 minutes of independent warm-up. Thirty seconds time interval was maintained between each handgrip strength testing. Heart rate was estimated manually. $VO_2\text{max}$ was estimated by Queen's College Step Test (McArdle, Katch, & Pechar, 1972). The instruments were calibrated prior to use and all measurements were taken on the subject's right side. Arm muscle girth, Arm-muscle area, arm area, arm fat area and arm fat index were calculated using standard methodologies (McArdle, Katch, & Pechar, 2001) as:

Arm muscle girth (cm) = $G_{\text{arm}} - (\pi \text{ Skin fold triceps})$; Arm muscle area, $\text{cm}^2 = [G_{\text{arm}} - (\pi \text{ Sf tri})]/4\pi$; Arm area (A), $\text{cm}^2 = (G_{\text{arm}})^2/4\pi$; Arm fat area, $\text{cm}^2 = \text{arm area} - \text{arm muscle area}$; Arm fat index, $\% \text{ fat area} = (\text{arm fat area}/\text{arm area})$, $G_{\text{arm}} = \text{Arm girth}$.

Statistical analysis

Standard descriptive statistics (mean \pm standard deviation) were determined for directly measured and derived variables. One way analysis of variance was tested for the comparisons of data among Indian inter-university volleyball players and controls, followed by post hoc Bonferroni test. Pearson's correlation coefficients were applied to establish the relationships among the variables measured. Data were analyzed using SPSS (Statistical Package for Social Science) version 14.0. A 5% level of probability was used to indicate statistical significance.

RESULTS

Descriptive statistics of various anthropometric, body composition, physical, physiological and arm anthropometric characteristics in volleyball players and controls are given in Table 1 and 2. Male volleyball players were taller (6.63%) and heavier (7.31%) while female volleyball players were slightly taller (0.31%) and lighter (3.74%) than their control counterparts. Both male and female volleyball players have higher mean values for chest and hip circumferences, femur and humerus biepicondylar diameters, percent lean body mass, basal metabolic rate (only in male players), percent water, right and left hand grip strength, Vo_2max , upper arm length, lower arm length, total arm length and arm muscle area (only in male players) and lesser mean values in biceps, triceps, sub scapular and calf (only in male players), percent body fat, heart rate, upper arm circumference, upper arm area, arm fat area and arm fat index (only in male players) than their control counterparts. One way analysis of variance showed significant ($p \leq 0.004-0.000$) between group differences in all the variables (except hip circumference) between volleyball players and controls.

Table 1. Descriptive statistics of various anthropometric and physiological characteristics in Indian volleyball players and controls.

Variables	Volleyball (n=63)				Controls (n=102)			
	Males		Females		Males		Females	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Height (cm)*	181.93	6.37	159.67	5.85	170.62	5.88	159.17	6.05
Weight (kg)*	69.09	69.09	49.96	7.51	64.38	11.03	51.83	8.97
BMI (kg/mL)**	20.66	2.46	19.62	2.79	22.15	3.56	20.46	3.8
Chest circumfe. (cm)***	87.39	7.07	82.66	4.26	85.18	7.35	82.28	7.32
Hip circumfe. (cm)	91.47	5.95	90.55	5.45	90.29	7	89.43	8.01
Fem. Biepic on. dia. (cm)*	8.89	1.03	8.02	1.2	8.14	0.86	7.42	1.02
Hum. bi-epicon. dia. (cm)*	6.77	0.58	5.74	0.72	6.18	0.76	5.49	0.71
Biceps skinfold (mm)*	6.83	2.01	9.44	2.16	10.54	2.44	12.38	4.94
Triceps skinfold (mm)*	10.17	3.56	14.72	3.08	15.1	4.67	16.86	5.28
Subscapular skinfold (mm)*	12.95	3.08	17.52	4.13	18.88	5.5	20.82	5.9
Calf skinfold (mm)*	11.5	3.24	20.24	4.84	15.98	3.55	17.98	6.45
Percent body fat (%)*	13.48	2.91	20.4	2.92	18.75	5.21	21.88	4.45
Percent lean body mass (%)	86.52	2.91	79.6	2.92	81.26	5.21	78.12	4.45
Basal metabolic rate (kcal)*	1783.58	161.31	1326.16	82.33	159.98	8.14	1352.92	106.23
Water percent (%)*	61.74	3.76	56.72	3.84	54.89	4.49	49.72	7.02
Right hand grip strength (kg)*	43.66	5.88	24.21	3.64	41.11	6.57	21.25	4.24
Left hand grip strength (kg)*	42.33	6.17	23.6	4.44	38.62	6.4	20.45	4.18
Heart rate (beats/min)*	99.05	2.72	101.6	6.11	119.31	13.32	123.2	12.07
Vo_2max (ml/kg/ min)*	69.73	3.82	47.04	1.13	61.22	5.59	43.04	2.22

* significant at 0.000 level, ** significant at .008 and *** significant at .004 level

Table 2. Descriptive statistics of various arm anthropometric variables in Indian volleyball players and controls.

Variables	Volleyball males (n=38)		Volleyball females		Control males (n=52)		Control females	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Upper arm length (cm)*	31.58	2.72	29.54	1.66	28.77	2.91	28.19	2.49
Lower arm length (cm)*	30.13	1.8	25.66	1.48	27.71	3.47	26.04	1.88
Total arm length (cm)*	81.84	4.42	72.86	2.94	75.04	3.82	70.82	3.76
Upper arm circumference (cm)*	26.24	2.62	23.16	2.00	26.97	2.91	24.52	2.99
Upper arm muscle area (cm ²)*	42.48	6.9	24.44	3.64	39.86	10.32	29.39	8.39
Upper arm area (cm ²)*	55.3	10.73	42.98	7.27	58.54	12.77	48.56	11.96
Upper arm bone free muscle area (cm ²)*	32.48	6.9	17.94	3.64	29.86	10.32	22.89	8.39
Upper arm fat area (cm ²)*	12.82	5.17	1853	5.47	18.68	6.86	19.17	8.2
Arm fat index*	22.47	6.00	42.42	7.61	32.00	9.25	38.95	11.47

*significant at 0.000 level, ** significant at .008 and *** significant at .004 level

Table 3 and 4 showed the correlation coefficients of BMI, percent body fat, right hand grip strength and Vo₂max with other anthropometric, body composition, physical and physiological variables in volleyball players and controls. In volley players, significantly positive correlations were found with BMI and other 19 variables, with percent body fat and 6 variables, with right hand grip strength and 20 variables and with Vo₂max and other 19 variables, and significantly negative correlations were found with percent body fat and other 16 variables, with right hand grip strength and other 7 variables and with Vo₂max with other 8 variables. Figures 1-4 showed the scattered plot of BMI, %body fat, hand grip strength (right dominant) and Vo₂max in volleyball players.

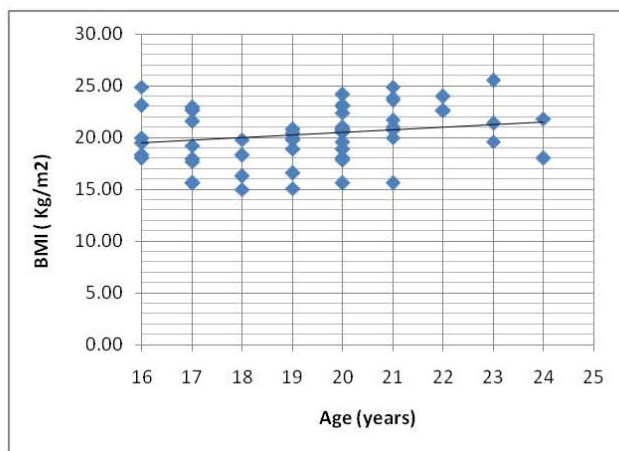
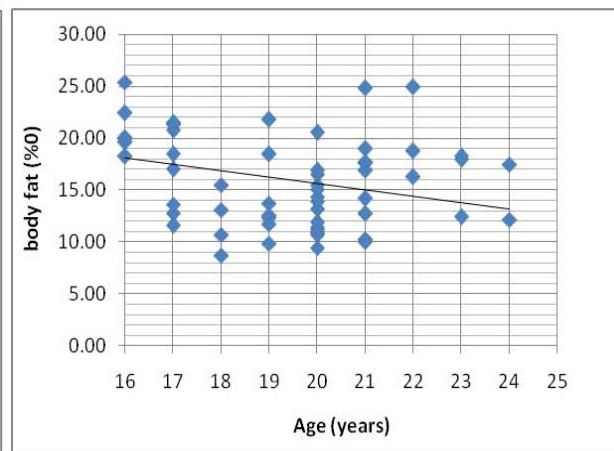
**Figure 1.** Scatter-plot of BMI in volleyball players**Figure 2.** Scatter-plot of % body fat in volleyball

Table 3. Correlation coefficients of BMI, percent body fat, right hand grip strength and Vo₂max with other anthropometric and physiological characteristics in Indian volleyball players and controls.

Variables	BMI		BF		RHGS		Vo ₂ max	
	VBP	Cont	VBP	Cont	VBP	Cont	VBP	Cont
Height (cm)	0.200	0.059	-0.585**	-0.213*	0.854**	0.704**	0.835**	0.620**
Weight (kg)	0.705**	0.857**	-0.279*	0.293**	0.761**	0.603**	0.685**	0.416**
Body mass index (kg/m ²)			0.24	0.463**	0.289*	0.293**	0.167	0.133
Chest circum. (cm)	0.794**	0.818**	0.015	0.445**	0.400**	0.269**	0.327**	0.087
Hip circum. (cm)	0.679**	0.762**	0.320*	0.457**	0.241	0.163	0.042	-0.018
Fem. Epicon. Dia. (cm)	0.447**	0.307**	-0.229	0.135	0.395**	0.383**	0.326**	0.323**
Hum. Epicon. Dia. (cm)	0.384**	0.365**	-0.486**	0.049	0.648**	0.459**	0.605**	0.343**
Biceps skinfold (mm)	0.261*	0.341**	0.777**	0.563**	-0.471**	-0.219*	-0.526**	-0.255**
Triceps skinfold (mm)	0.313*	0.497**	0.845**	0.773**	-0.434**	-0.1	-0.523**	-0.182
Subscapular skinfold (mm)	0.355**	0.614**	0.852**	0.832**	-0.420**	-0.095	-0.526**	-0.177
Calf skinfold (mm)	0.204	0.383**	0.796**	0.462**	-0.638**	-0.143	-0.719**	-0.216*
Body fat (%)	0.24	0.463**			-0.608**	-0.182	-0.736**	-0.253*
Lean body mass (%)	-0.24	-0.463**	-1.000**	-1.000**	0.608**	0.182	0.736**	0.253*
Right hand grip strength (kg)	0.289*	0.293**	-0.608**	-0.182			0.839**	0.747**
Left hand grip strength (kg)	0.297*	0.328**	-0.586**	-0.212*	0.958**	0.957**	0.841**	0.742**
Basal metabolic rate (Kcal)	0.506**	0.615**	-0.464**	0.03	0.865**	0.748**	0.817**	0.619**
Water (kg)	0.608**	0.550**	-0.345**	0.103	0.793**	0.506**	0.743**	0.433**
Water (%)	-0.117	-0.168	-0.474**	-0.352**	0.501**	0.408**	0.600**	0.403**
Heart rate (beat/min)	0.053	0.147	0.114	-0.046	-0.119	-0.117	-0.400**	-0.530**
Vo ₂ max (ml/kg/min)	0.167	0.133	-0.736**	-0.253*	0.839**	0.747**		

* Significant at .05 level; ** Significant at .01 level; BMI= Body mass index. BF= Body fat. RHGS= Right hand grip strength. VBP= Volleyball players. Cont= Control.

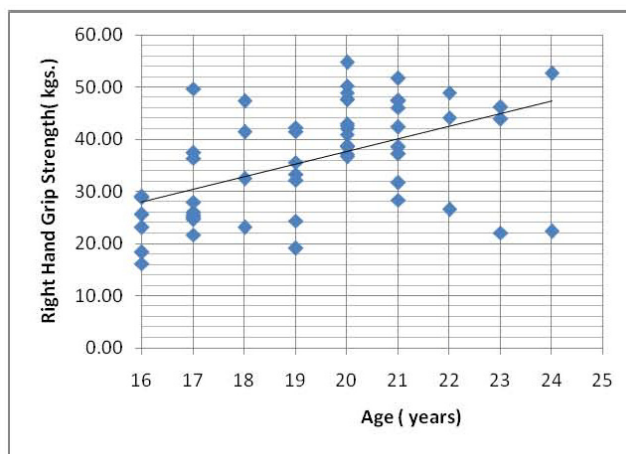


Figure 3. Scatter-plot of hand grip strength (right dominant) in volleyball players.

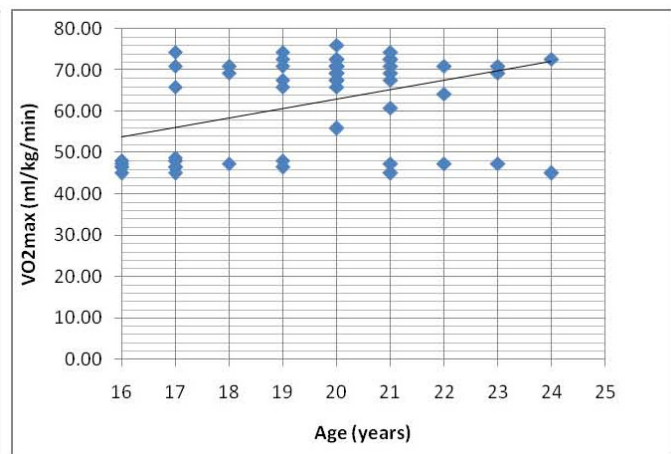


Figure 4. Scatter-plot of Vo₂max in volleyball players.

Table 4. Correlations coefficients of BMI and percent body fat, right hand grip strength and Vo₂max with other arm anthropometrics characteristics in Indian volleyball players and controls.

Variables	BMI		BF		RHGS		Vo ₂ max	
	Volley	Contr	Volley	Contr	Volley	Contr	Volley	Contr
Upper arm length (cm)	0.108	0.102	-0.279*	0.208*	0.417**	0.218*	0.358**	0.132
Lower arm length (cm)	0.279*	0.158	-0.549**	-0.178	0.776**	0.321**	0.733**	0.309**
Total arm length (cm)	0.226	0.115	-0.471**	-0.016	0.747**	0.500**	0.716**	0.490**
Arm circumference (cm)	0.761 **	0.767**	-0.031	0.288**	0.618**	0.482**	0.512**	0.333**
Arm muscle area (cm ²)	0.508**	0.504**	-0.491**	-0.154	0.833**	0.549**	0.800**	0.438**
Upper arm area (cm ²)	0.749**	0.770**	-0.035	0.287**	0.620**	0.479**	0.515**	0.322**
Upper arm bone free muscle area (cm ²)	0.548**	0.501**	-0.422**	-0.111	0.796**	0.443**	0.741**	0.311**
Upper arm Fat area	0.507**	0.642**	0.808**	0.728**	-0.315*	0.062	-0.455**	-0.056
Arm fat index	0.095	0.214*	0.877**	0.677**	-0.696**	-0.260**	-0.794**	-0.313**

* Significant at .05 level; ** Significant at .01 level; BMI= Body mass index. BF= Body fat. RHGS= Right hand grip strength. Contr= Control.

DISCUSSION AND CONCLUSION

Anthropometric and morphological characteristics play a vital role in determining the success of sportspersons (Rico-Sanz, 1998; Wilmore & Costill, 1999; Keogh, 1999). Specific physical characteristics or anthropometric profiles are required for the highest level of performance in a specific sport (Claessens, Lefevre, Beunen, & Malina, 1999; Bourgois et al., 2000; Reilly, Bangsbo, & Franks, 2000; Gabbett, 2000; Ackland, Ong, Kerr, & Ridge, 2003; Slater et al., 2005).

1. Anthropometric characteristics

In volleyball, teams compete by manicores handling the ball above the head, height is considered to be the most important physical attribute. In the present study, the mean height of the male players (181.93±6.37 cm) was greater than the male volleyball players of West Bengal, India (173.10±4.19 cm) reported by Bandyopadhyay (2007), but lesser than the English (191.00±5.0 cm) (Duncan et al., 2006), while in female players, the mean height (159.67±5.85 cm) was lesser than the American (176.70±4.60 cm) (Ferris, Signorile, & Caruso, 1995) and Japanese (168.70±5.89 cm) (Tsunawake et al., 2003) female volleyball players. In the study, significantly greater body weight among volleyball players might be disadvantageous for them in attaining a good jumping height as they have to lift a greater weight. The skinfold thickness is examined for the evaluation of the nutritional status and physical changes with training. In the present study, the skinfold thickness of four sites, biceps, triceps, subscapular and calf, of male volleyball players were more than the findings of Bandyopadhyay (2007).

2. Body composition

Body composition greatly affects the energy-related physical strength and skill in various sports (Kitagawa, Ikuta, Hara, & Hirota, 1974). The estimated % body fat was lower in both sexes than controls and the findings of Kovaleski, Parr, Hornak, and Roitman (1980), Spence, Disch, Fred, and Coleman (1980), Tsunawake et al. (1995), Filaire, Duche, and Lac (1998) in volleyball players. On the other hand, % LBM

and water % was reported to be higher than controls. These differences between players and controls might be due to regular physical exercise and prolonged training effect.

3. Physical variables

In volleyball players of both sexes, hand grip strength (right dominant) was reported to be higher than controls, showing biomechanical advantages in the game. When comparisons were made with the data of Barut et al. (2008), Indian volley ball players have higher values for this trait.

4. Physiological variables

Several studies have documented the physiological and anthropometric characteristics of volleyball players (Fleck, Case, Puhl, & Van-Handle, 1985; Hosler, Morrow, & Jackson, 1978; Spence, Disch, Fred, & Coleman, 1980). In the present study, Indian volleyball players have lesser value for heart rate and greater value for VO_2max than controls. These differences might be due to regular physical exercise and training in volleyball players. In fact, volleyball is an intermittent sport. It requires players to participate in frequent short bouts of high-intensity exercise, followed by periods of low-intensity activity (Kunstlinger, Ludwig, & Syegemann, 1987; Viitasalo et al., 1987). The high intensity bouts of exercise, coupled with the total duration of the match requires players to have well-developed aerobic and anaerobic alactic (ATP-CP) energy systems (Polglaze & Dawson, 1992; Viitasalo et al., 1987). As a result, volleyball players require well-developed speed, agility, upper-body and lower body muscular power, and maximal aerobic power (VO_2max).

5. Arm anthropometry

Though volleyball players of both sexes have greater upper arm length, lower arm length, total arm length, arm muscle area than controls, they have lesser arm fat area, arm circumference and arm fat index, these differences might be due to less fat on the arm in the players. Regular training program of volleyball players made these differences.

Changes in the physiological and anthropometric characteristics of volleyball players in response to training and over the course of a season have also been documented (Fardy, Hritz, & Hellerstein, 1976; Franks & Moore, 1969; Gabbett & Georgieff, 2007; Hascelik, Basgoze, Turker, Narman, & Ozker, 1989). Studies of the effect of volleyball and physical conditioning training on the physiological and anthropometric characteristics of players are equivocal, with reports of increased (Fardy, Hritz, & Hellerstein, 1976; Franks & Moore, 1969; Hascelik, Basgoze, Turker, Narman, & Ozker, 1989), decreased or unchanged fitness (Gabbett & Georgieff, 2007) in response to training. In addition, it was recently shown that volleyball training significantly improved the skill levels of talent-identified volleyball players, without significantly altering skinfold thickness and VO_2max (Gabbett & Georgieff, 2007), showing skill execution was as important as physiological and anthropometric characteristics for predicting success in junior volleyball players.

The data presented in the present study carry immense practical application and should be useful in future investigation on player selection, talent identification in volleyball and training program development.

REFERENCES

1. ACKLAND TR, ONG KB, KERR DA, RIDGE B. Morphological characteristics of Olympic sprint canoe and kayak paddlers. *Journal of Science and Medicine in Sport*. 2003; 6:285-294. doi:10.1016/S1440-2440(03)80022-1 [[Back to text](#)]

2. BANDYOPADHYAY A. Anthropometry and body composition in soccer and volleyball players in West Bengal, India. *Journal of Physical Anthropology*. 2007; (4):501-505. doi:[10.2114/jpa2.26.501](https://doi.org/10.2114/jpa2.26.501) [[Back to text](#)]
3. BARUT C, DEMIREL P, KIRAN S. Evaluation of hand anthropometric measurements and grip strength in basketball, volleyball and handball players. *Anatomy*. 2008; 2:55-59. doi:[10.2399/ana.08.055](https://doi.org/10.2399/ana.08.055) [[Back to text](#)]
4. BOUCHARD C, LORTIE G. Heredity and endurance performance. *Sports Medicine*. 1984; 1:38-64. [[Abstract](#)] [[Back to text](#)]
5. BOURGOIS J, CLAESSENS AL, VRIJENS J, PHILIPPAERTS R, RENTERGHEM BV, THOMIS M, JANSSENS M, LOOS R, LEFEVRE J. Anthropometric characteristics of elite male junior rowers. *British Journal of Sports Medicine*. 2000; 34:213-216. doi:[10.1136/bjism.34.3.213](https://doi.org/10.1136/bjism.34.3.213) [[Back to text](#)]
6. CHATTERJEE S, CHATTERJEE P, BANDYOPADHYAY A. Skinfold thickness, body fat percentage and body mass index in obese and non-obese Indian boys. *Asia Pacific Journal of Clinical Nutrition*. 2006; 15:232-235. [[Full Text](#)] [[Back to text](#)]
7. CLAESSENS AL, LEFEVRE J, BEUNEN G, MALINA RM. The contribution of anthropometric characteristics to performance scores in elite female gymnasts. *Journal of Sports Medicine and Physical Fitness*. 1999; 39:355-360. [[Abstract](#)] [[Back to text](#)]
8. DUNCAN MJ, WOODFIELD L, AL-NAKEEB Y. Anthropometric and Physiological characteristics of junior elite volleyball players. *British Journal of Sports Medicine*. 2006; 40:649-51. doi:[10.1136/bjism.2005.021998](https://doi.org/10.1136/bjism.2005.021998) [[Back to text](#)]
9. DURNIN JVGA, WOMERSLEY J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *British Journal of Nutrition*. 1974; 32:77-97. [[Back to text](#)]
10. FAGARD R, BIELEN E, AMERY A. Heritability of aerobic power and anaerobic energy generation during exercise. *Journal of Applied Physiology*. 1991; 70:357-362. [[Abstract](#)] [[Back to text](#)]
11. FARDY PS, HRITZ MG, HELLERSTEIN HK. Cardiac responses during women's intercollegiate volleyball and physical fitness changes from a season of competition. *Journal of Sports Medicine*. 1976; 16:291-297. [[Back to text](#)]
12. FERRIS DP, SIGNORILE F, CARUSO JF. The relationship between physical and physiological variables and volleyball spiking velocity. *Journal of Strength and Conditioning Research*. 1995; 9(1):32-36. [[Abstract](#)] [[Back to text](#)]
13. FILAIRE E, DUCHE P, LAC G. Effects of training for two balls on the saliva response of adrenocortical hormones to exercise in elite sportswomen. *European Journal of Applied Physiology*. 1998; 77:452-456. doi:[10.1007/s004210050359](https://doi.org/10.1007/s004210050359) [[Back to text](#)]
14. FLECK S, CASE S, PUHL J, VAN-HANDLE P. Physical and physiological characteristics of elite women volleyball players. *Canadian Journal of Applied Sport Science*. 1985; 10:122-126. [[Abstract](#)] [[Back to text](#)]
15. FRANKS BD, MOORE GC. Effects of calisthenics and volleyball on the AAHPER fitness test and volleyball skill. *Research Quarterly*. 1969; 40:288-292. [[Back to text](#)]
16. FRY AC, KRAEMER WJ, WESEMAN CA, CONROY BP, GORDON SE, HOFFMAN JR, MARESH CM. The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *Journal of Applied Sport Science Research*. 1991; 5:174-181. [[Back to text](#)]
17. GABBETT TJ. Physiological and anthropometric characteristics amateur rugby players. *British Journal of Sports Medicine*. 2000; 34:303-307. doi:[10.1136/bjism.34.4.303](https://doi.org/10.1136/bjism.34.4.303) [[Back to text](#)]

18. GABBETT T, GEORGIEFF B. Physiological and anthropometric characteristics of Australian junior national, state, and novice volleyball players. *Journal of Strength Conditioning Research*. 2007; 21(3):902-908. [[Abstract](#)] [[Back to text](#)]
19. GLADDEN LB, COLACINO D. Characteristics of volleyball players and success in a national tournament. *Journal of Sports Medicine*. 1978; 18:57-64. [[Back to text](#)]
20. HASCELIK Z, BASGOZE O, TURKER K, NARMAN S, OZKER R. The effects of physical training on physical fitness tests and auditory and visual reaction times of volleyball players. *Journal of Sports Medicine and Physical Fitness*. 1989; 29:234-239. [[Abstract](#)] [[Back to text](#)]
21. HOSLER WW, MORROW JR, JACKSON AS. Strength, anthropometric, and speed characteristics of college women volleyball players. *Research Quarterly*. 1978; 49:385-388. [[Back to text](#)]
22. HOUTKOOPER BL, TOMTHY GL, SCOTT BG, WANDA HH. Why bioelectric impedance analysis should be used for estimating adiposity. *American Journal of Clinical Nutrition*. 1996; 64:436-448. [[Full Text](#)] [[Back to text](#)]
23. KEOGH J. The use of physical fitness scores and anthropometric data to predict selection in an elite under-18 Australian rules football team. *Journal of Sport Science and Medicine*. 1999; 2:125-133. [[Abstract](#)] [[Back to text](#)]
24. KITAGAWA K, IKUTA K, HARA Y, HIROTA K. Investigation of lean body mass as a limiting factor of maximum oxygen uptake. *Japan Journal of Physical Fitness and Sports Medicine*. 1974; 23:96-100. [[Back to text](#)]
25. KOVALESKI JE, PARR RB, HORNAK JE, ROITMAN JL. Athletic profile of women college volleyball players. *The Physician and Sports Medicine*. 1980; 8(2):112-116. [[Back to text](#)]
26. KUNSTLINGER U, LUDWIG H G, STEGEMANN J. Metabolic changes during volleyball matches. *International Journal of Sports Medicine*. 1987; 8:315-322. doi:10.1055/s-2008-1025676 [[Back to text](#)]
27. LOHMANN TG, ROCHE AF, MARTORELL R. *Anthropometric Standardization Reference Manual*. Champaign, IL: Human Kinetics Books; 1988. [[Back to text](#)]
28. MCARDLE WD, KATCH FI, KATCH VL. *Exercise physiology: Energy, Nutrition and Human Performance*. Lippincott Williams and Wilkins; 2001. [[Back to text](#)]
29. MCARDLE WD, KATCH FL, PECHAR GS. Reliability and interrelationship between maximal oxygen intake, physical work capacity and step test scores in college women. *Medicine and science in Sports and Exercise*. 1972; 4:182-6. [[Back to text](#)]
30. MORROW JR, JACKSON AS, HOSLER WW, KACHURIK JK. The importance of strength, speed, and body size for team success in women's intercollegiate volleyball. *Research Quarterly*. 1979; 50:429-437. [[Back to text](#)]
31. PEDEGANA LR, ELSNER RC, ROBERTS D, LANG J, FAREWELL V. The relationship of upper extremity strength to throwing speed. *American Journal of Sports Medicine*. 1982; 10(6):352-354. doi:10.1177/036354658201000606 [[Back to text](#)]
32. POLGLAZE T, DAWSON B. The physiological requirements of the positions in state league volleyball. *International Journal of Sports Science and Coaching*. 1992; 15:32-37. [[Back to text](#)]
33. REILLY T, BANGSBO J, FRANKS A. Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*. 2000; 18(9):669-683. doi:10.1080/02640410050120050 [[Back to text](#)]
34. RICO-SANZ J. Body composition and nutritional assessments in soccer. *International Journal of Sport Nutrition*. 1998; 8(2):113-123. [[Abstract](#)] [[Back to text](#)]
35. SLATER GJ, RICE AJ, MUJIKI I, HAHN AG, SHARP K, JENKINS DG. Physique traits of lightweight rowers and their relationship to competitive success. *British Journal of Sports Medicine*. 2005; 39:736-741. doi:10.1136/bjism.2004.015990 [[Back to text](#)]

36. SPENCE DW, DISCH JG, FRED HL, COLEMAN AE. Descriptive profiles of highly skilled women volleyball players. *Journal of Medicine and Science in Sports and Exercise*. 1980; 12:299-302. [[Abstract](#)] [[Back to text](#)]
37. TSUNAWAKE N, TAHARA Y, MOJI K, MURAKI S, MINOWA K, YUKAWA V. Body composition and physical fitness of female volleyball and basketball players of the Japan inter-high school championship teams. *Applied Human Science: Journal of Physiological Anthropology*. 2003; 22(4):195-201. [[Abstract](#)] [[Back to text](#)]
38. TSUNAWAKE N, TAHARA Y, YUKAWA K, KATSURA T, HARADA H, KIKUCHI Y. Characteristics of body shape of female athletes based on factor analysis. *Applied Human Science: Journal of Physiological Anthropology*. 1995; 14:55-61. [[Abstract](#)] [[Back to text](#)]
39. VIITASALO J, RUSKO H, PAJALA O, RAHKIL AP, AHIL AM, MONTONEN H. Endurance requirements in volleyball. *Canadian Journal of Applied Sports Sciences*. 1987; 12:194-201. [[Back to text](#)]
40. WILMORE JH, COSTILL DL. *Physiology of Sports and Exercise*. 2nd ed. Human Kinetics, Champaign; 1999. Pp. 490-507. [[Back to text](#)]