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Performance oriented upper arm anthropometric measurements in dominant endomorph, mesomorph and ectomorph (9-11 years) trained male tennis players

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Abstract
Objectives: The main objective of this study was to find out whether any significant differences exist or not in some performance oriented upper arm anthropometric measurement and body composition among the three dominant somatotypes.
Methods: Total 21 trained male tennis players 9-11 years (mean age10.46 years) were participated in this study and their body size, body composition and body type were determined by ISAK recommended method. Players were classified according to their somatotypes into dominant endomorph, mesomorph and ectomorph. Some performance oriented anthropometric measurements were also measured by using standard methods.
Results: One way ANOVA followed by Scheffe's tests (p<0.05) was done among the three dominant somatotypes. Hand span, hand length, hand width, cubit length, and wrist circumference were found to be significantly (p<0.05) differ among the three dominant groups.
Conclusion: This finding states that trained players have their own body types. Different performance oriented upper arm measurements were also differ among these groups. It will be more effective and appropriate for the players when they classified according to their body types and designing of sport equipments on the basis of their somatotypes.

Keywords: Body types, hand span, hand length, hand width, cubit length, wrist circumference

Introduction
In modern sports arena a basic question is how the trained individual be classified and what are the criteria for comparative analysis among the trained individual. Trained players are mainly classified on their chronologic age, sex, ethnicity, type of game etc. Moreover, different variables measured in trained players are compared with the so called reference values. It is obvious that trained individual differ from untrained one due to their physiologic adaptation and by comparing this, one can only justify the qualitative aspect of training. Quantitative aspect of physical training is directly associated with the development of physiological system of the trained player. An individual considered as trained when their physiological system as well as physical traits is modulated according to their bodily demand under the influence of effective physical training. Proper quantification of training is most important aspect in modern sports competition. There is always a controversial issue that on which basis trainer quantifies the training. Moreover, performance of a player mainly depends upon skill and body build (W.H. Sheldon *et al*., 1940) [15]. Skill of a game can be improved by performance oriented training and proper sports equipments. Proper sports equipment designing is another vital aspect to perform better in the competition. So, on which basis the equipment designing be more appropriate and effective for the player is a major concern. The other major factor, which directly influences the performance level, is body build. Body build comprises body size, body composition and body type or somatotypes. In 1940, W.H. Sheldon introduced the term somatotypes. Most of the researcher gives importance to body size and body composition and surprisingly neglected body type or somatotypes, the most important aspect of body build. Somatotypes of a person actually reflect the physical traits related to physiological system of the body. Determination of somatotypes is therefore having utmost importance to get basic information about the physiologic and metabolic status of the body.

Athletic performance is influenced by the structure and shape of the athlete. Athletes with different somatotypes exhibit outstanding performance during exercise and physical training (J. M. Tanner *et al*., 1960; R. Bulbulian, 1984; M.H. Slaughter *et al*., 1976; C.W. Duperitus, 1951; W.W. Bolonchuk, 1990) [13, 6, 18, 7, 3]. Proper physical exercise and training mobilize the development of new muscle mass which ultimately change the shape and structure of the athlete. External changes can be easily identified by classifying the athlete according to their somatotypes. These external changes can only be possible by modifying the internal metabolic activities of athlete. Heath and Carter (1967) [8] introduced the method for somatotypes which is almost identical to measurements of anthropometrically determined body composition. After that many studies have been carried out to relate body composition variables and somatotypes (R.A. Boileau *et al*., 1977; M.H. Slaughter *et al*., 1980; M.H. Slaughter *et al*., 1995) [2, 19, 17]. All these studies suggested that endomorph is more fatty and heavier than mesomorph and ectomorph, mesomorph is comparatively more muscular than endomorphs and ectomorph, and ectomorph is the most lean and thin among the three groups. Thus, these evidences suggest that there is a definite relationship between structural components and somatotypes.

The present study mainly deals with the classification of trained male players according to their dominant somatotypes. As the participated players had completed at least two years of physical training under the guidance of trainers, it was expected that some physical and physiological improvement must be reflected among the players. Moreover, body types after physical training in male trained junior players whether identical or different was another major concern of this study. This study involved such an age range that where usually hormonal influences not very effective in male players though this observation could not claimed it. The goal of the study was to find out any significant differences in some selected performance oriented upper arm anthropometric measurements among the three dominant group of male trained tennis player.

Methods

Twenty one (21) trained male players between ages ranges of 9-11years were participated in this cross sectional study. Individual NFHS (National Standard of Living Index) and SCAT (Sports Competition Anxiety Test) were carried out in each participant. Prior permission is obtained from Institutional Ethics Committee. They were trained for minimum 2 years and maximum 4 years and participated in district or regional competition.

Anthropometric measurements

All measurements were taken on the same day to avoid technical error by the Level 1 Anthropometrics accredited by International Society for Advancement of Kinanthropometry (ISAK), according to the procedure stated on the ISAK manual (www.isakonline.com).

Body Size

Stature (cm) was the perpendicular distance between the transverse planes of the Vertex and the inferior aspect of the feet. It is measured by Stadiometer (minimum range of measurement 60cm to 220cm). Body mass (kg) was measured with an electronic weighing machine.

Body Type or Somatotypes

Skin fold thickness (biceps, triceps, subscapular, and supraspinale) for determining the fat% and total fat content were measured with a skin fold caliper which requires a constant closing compression of 10 $g.mm^{-2}$ throughout the range of measurements. The subject was asked to assume a relaxed standing position with the right arm hanging by the side and the hand in mid-prone position. Biceps skin fold was measured from the point on the anterior surface of the arm at the level of mid-acromiale-radiale land mark, in the middle of the muscle belly. Triceps skin fold was measured from the point on the posterior surface of the arm, in the mid-line, at the level of marked mid-acromiale-radial landmark. Subscapular skin fold measurement was taken with the fold running obliquely downwards from the sub scapular landmark at 45^0 angles. Supraspinale skin fold measurement was taken from the intersecting point of two lines- (i) the line from the marked iliospinale to the anterior axillaries border and (ii) the horizontal line at the level of marked iliocristale.

Anthropometric tape which was non-extensible, flexible, not wider than 7 mm and have a stub (blank area) of at least 4 cm before zero line was used to measure girth (arm and calf) and circumferences (chest, waist, hip, mid-thigh, upper thigh). The arm girth was taken from the circumference of the arm at the level of mid-acromiale-radiale site, perpendicular to the long axis of arm. Similarly calf girth was taken from the circumference of leg at the level of medial calf skin fold site, perpendicular to its long axis. The measurement of the circumference of the thorax at the level of the mesosternale site, perpendicular to the long axis of the thorax was the chest circumference. Waist circumference was the circumference of the abdomen at this narrowest point between the lower coastal (10^{th} rib) border and the top of the iliac crest, perpendicular to the long axis of the trunk. The circumference measured from the buttocks at the level of their greatest posterior protuberance, perpendicular to the long axis of the trunk. The circumference of the mid-thigh was measured at the level of the mid-trochanterion-tibialelaterale site, perpendicular to its long axis. Upper thigh circumference was measured from the site of the thigh, 1 cm distal to the gluteal fold site, perpendicular to its long axis.

Sliding caliper has a branch length of at least 10 cm, an application face width of 1.5 cm and accurate within 0.05 cm, was used for measuring breadth (biepicondylar humerus and femur). Biepicondylar humerus and femur were measured from the distance between the most lateral aspect of the lateral humeral and femoral epicondyle and the most medial humeral and femoral epicondyle respectively.

Heath and Carter (1967) [8] method was followed for the determination of somatotypes. The following equations were used for calculating somatotypes. Endomorph = -0.7182 + 0.1454 x $\sum SF$ - 0.00068 x $\sum Sf^2$ + 0.0000014 x $\sum SF^3$ Where, $\sum SF$ = (triceps + biceps + subscapular + supraspinale skin fold in mm) x (170.18/height in cm.). Mesomorph = 0.858 x humerus breadth + 0.601 x femur breadth + 0.188 x corrected arm girth + 0.161 x corrected calf girth – height x 0.131 + 4.5. Three different equations were used to calculate ectomorph according to the height-weight ratio (HWR): If HWR was greater than or equal to 40.75 then, Ectomorph = 0.732 x HWR -28.58. If HWR was less than 40.75 and greater than 38.25 then, Ectomorph = 0.463 x HWR – 17.63. If HWR was equal to or less than 38.25 then, Ectomorph = 0.1.

Body Composition (Body Fat Percentage and Total Fat Content)

From the four different skin fold thickness, the Body Density

(g/mm^3) was measured using the generalized equation for body density and the Total Body Fat Percentage (%) was calculated using the equation derived by Brozek *et al* (1963) and Siri (1956).The Total Fat Mass (kg) was evaluated by using the values of Total Body Fat Percentage (%) and Body Mass i.e. Weight (kg). Equations for calculating Body Density (g/mm^3), Total Fat percentage (%), Total Fat Mass (kg) were given below.
Body Density, For Male =1.1620-0.0630log (Biceps + Triceps + Subscapular + Supraspinale in mm) Total Body Fat Percentage (%) = ((4.45/Body density)-4.142) x 100 Total Body Fat Mass (kg) = (% of Body Fat/100) x Body Weight in kg.

Performance Oriented Anthropometric Measurements
Hand was placed, palm down on a flat surface. The fingers were outstretched as far as possible. Measurement was taken from the linear distance between the outside of the thumb to the outside of the little finger (B. Bryan *et al*., 1992) [5].
Hand length was the measurement from the bottom edge of palm to the tip of the middle finger (B. Bryan *et al*., 1992) [5].
A measuring tape was wrapped around by the dominant hand just below knuckles, excluding the thumb, and makes a fist to measure the hand width (B. Bryan *et al*., 1992) [5].
Arm span was the physical measurement of the length from one end of an individual's arms to the other when raised parallel to the ground at shoulder height at a 90º angle (B. Bryan *et al*., 1992) [5].
A measuring tape was wrapped around the wrist (right or left) and the end of the tape measure and brings it all the way around. This was the circumference of wrist (B. Bryan *et al*., 1992) [5].
A cubit was an ancient measurement of length based on the distance from the elbow to the tip of the longest finger (M.H. Stone, 2014) [20].

Statistical Analysis
The Mean and Standard deviation, One-way ANOVA and Scheffe's tests were computed (with software SPSS version 16) for statistical analysis and confidence level was fixed at 95% ($p<0.05$).

Results
Table 1 represents age (years), height (cm), weight (kg), total fat mass (kg) and lean body mass (kg) in 9-11 years trained male dominant endomorph, mesomorph and ectomorph tennis players. Insignificant differences were found in age and height among the three groups. Body weight, total fat mass and lean body mass significantly ($p<0.05$) differs among trained dominant endomorph, mesomorph and ectomorph tennis players. Scheffe's test confirms that insignificant difference existing between dominant endomorph with mesomorph and mesomorph with ectomorph in body weight. Total fat mass between dominant mesomorph and ectomorph significantly differ in trained tennis players. Lean body mass was significantly ($p<0.05$) differ between endomorph and mesomorph but insignificantly differ between mesomorph with ectomorph and ectomorph with endomorph after Scheffe's test.
Table 2 represents hand span (cm), land length (cm), hand width (cm), arm span (cm), wrist circumference (cm) and cubit Length (cm) of dominant endomorph, mesomorph and ectomorph male tennis players. Hand span, hand width, wrist circumference and cubit length were significantly ($p<0.05$) differ among the three dominant groups. Significant differences in hand span, hand length and cubit length between dominant endomorph and mesomorph were found after performing Scheffe's test. Though hand width and wrist circumference among the three groups were differ significantly ($p<0.05$), but insignificant differences were observed between endomorph with mesomorph, mesomorph with ectomorph and ectomorph with endomorph after Scheffe's test.

Discussion
Despite the enormous importance in body build for athletic performance (T.R. Ackland *et al*., 2012; N.R. Rodriguez, 2009; R.M. Malina, 2007) [1, 12, 11] appropriate reference values for the athletic population have been lacking. In this study, body build and some performance oriented anthropometric measurements are considered in trained 9-11 years male tennis players. Tennis is one of the most worldwide popular sports which comprise high intensity, short term actions and pauses of varying length[20]. Success in sport needs the optimal combination of technical, tactical, physical and anthropometric characteristics. Indeed, experts such as coaches and scientists believe that the success of tennis is associated with anthropometric characteristics of players (A. Khasawneh, 2015) [10]. Scientists define anthropometric measurements as the study of human body measurements and its different parts and revealing its structural differences. Zawawi (2012) [21] pointed out that anthropometric measurements depend on calculating the amounts of external body structures. Anthropometric measurements also contribute to the refining of athletes' physical skills starting with the junior stage until the Olympic level[22]. Therefore, anthropometric and morphological requirements are considered as a decisive factor in different sports and are also linked to many physical abilities (S. Zawawi, 2012) [21]. Additionally, anthropometric measurements have important role in talent identification and a major predictor of success in competitive sport (A. Khasawneh, 2015; S. Saeid, 2008) [10, 14].
This study reveals that though the players are almost under the same physical training programmed, but they differ in their body composition and somatotypes. Generally, in this age range (9–11years) individual does not show any remarkable differences in their physiological functions and physical traits. Moreover, 8-12 years age range is considered as the best time to pick up athletes. We have found insignificant differences in age and height among the three groups and significant differences in body weight, total fat mass and lean body mass (Table1). Significant difference in total fat mass between mesomorph and ectomorph and lean body mass between endomorph and mesomorph reveals that even in this age range (9-11 years) body composition differs in trained players. These changes in body composition might be due to their physiologic as well as metabolic demand of the body. It indicates though chronological age and height may not be differing among three dominant somatotypes, but still they differ in body build. So it is very important for coaches to evaluate the body type and body composition before making any training schedule to get maximum benefit and minimum sports injury. As tennis is a most exhaustive and powerful racquet sport, it needs more muscle mass and high level of cardio respiratory fitness. Not only that, as sports equipment has a definite role in improvement of performance level, the designing of sports accessories should be more appropriate and better performance oriented when body composition and somatotypes are considered for equipment

designing.

In this study, it is observed that most the trained male tennis players of 9-11 years age have mesomorphic endomorphic balanced somatotypes. Mesomorphic ectomorph is sometimes desired for height-important sports like tennis, prevalence of these somatotypes is also found in this study. Somatotypes components are not homogenous, not even in the groups singled out by quality. There are significant differences within the same sport and in terms of playing position. Therefore it might be concluded that type and intensity of training can lead to diversity in somatotypes of the trained players within the same sport.

Body size is an important factor in success, whether to be short, tall, heavy or light. From this study it might be concluded that, as there is insignificant differences in height among the 3 groups of dominant endomorph, mesomorph and ectomorph 9-11 years trained male tennis players, they might have the equal advantages in the competition in respect to height.

The upper extremities play an important role in tennis. This study involves few performance oriented anthropometric measurements in trained tennis players to find out whether any significant differences exist or not among the three dominant somatotypes. The hand spans and hand length, associated with the proper griping of tennis racquet, help in better performance level during competition. These anthropometric measurements are also essential for proper designing of sports equipments. Even in this small age range (9-11), dominant mesomorph shows higher hand span, hand length and cubit length than endomorph which is advantageous for proper griping in tennis racquet and servicing the ball more efficiently (Table 2). Significant differences in wrist circumference among the three dominant somatotypes indicate variation. Arm span, which is another major measurement associated with tennis game, not significantly differ among the three dominant somatotypes, might be due to insignificant differences in height among the three dominant somatotypes.

Hand length and hand width is an excellent predictor of body surface area and body mass. Moreover, athletes with longer fingers and larger hand surfaces enjoy stronger grip power. Hand span influences optimal grip strength. In this study hand span (cm), hand length (cm) and hand width (cm) differs significantly among the three groups of dominant endomorph, mesomorph and ectomorph trained male tennis players. Highest values of hand span, hand length and hand width is observed in case of dominant mesomorph players. Thus it might be concluded that they enjoys a stronger grip power and training seems to have a positive effect on these players.

Cubit length (cm) is based on forearm length. In a research study of performance oriented anthropometry, it is suggested that tennis being a unilateral game requires a stronger grip, developing stronger forearm. In this study, there is significant differences in cubit length among the three groups of 9-11 years aged dominant endomorph, mesomorph and ectomorph trained male tennis players. Dominant mesomorph has the highest cubit length than the endomorph and ectomorph. Thus it may be concluded that training has led to development of stronger forearm in mesomorph and therefore a positive effect of training in these players is observed.

Performance oriented anthropometric measurement including greater dominant arm wrist extension/flexion and forearm pronation strength is common and normal in young elite tennis players. These strength relations indicate sport specific muscular adaptations in the dominant tennis playing extremity. In this study, there is significant differences in wrist circumference among the three groups of 9-11 years aged dominant endomorph, mesomorph and ectomorph trained male tennis players. Dominant mesomorph has the greatest wrist circumference than the endomorph and ectomorph. From this observation, it might be concluded that there is significant differences in muscular adaptation in wrist and forearm among the three groups. Mesomorph with the greatest value of wrist circumference is likely to have better grip strength and improved performance in tennis. There is a significant correlation between arm span and height. Therefore, in this study, the insignificant differences of arm span observed among the three groups of 9-11 years trained male dominant endomorph, mesomorph and ectomorph tennis players may be due to the insignificant difference in height among these three groups.

This study provides the differences in body build and some performance related anthropometric measurements including height, weight, total fat mass, lean body mass, hand span, hand length, hand width, cubit length, arm span, wrist circumference among the trained junior tennis players aged 9-11 years. This age range is (9-11years) in between childhood and puberty, and more appropriate to find out any physical development after exposure to 2 -3 years of physical training.

Analysis of somatotypes in tennis players provides a reference frame to control the training process in order to help/ improve athletes ' performance, and to improve talent detection and identification in tennis. Moreover, sports engineer can design proper tennis equipments according to their somatotypes for better performance. In this study, while analyzing the body type or somatotypes in junior (9-11 years) male trained tennis players, they are categorized into three groups dominant endomorph, mesomorph and ectomorph. But it is observed that most of the trained players have meso - endomorphic balanced somatotypes. Mesomorphic ectomorph is sometimes desired for height-important sports like tennis, prevalence of these somatotypes is also found in this study. Therefore it can be concluded that playing position, nutrition and intensity of training has lead to diversity in somatotypes of the trained players.

The compilation of performance oriented anthropometric data is a much needed and worthwhile to design tools and equipment in sports and others areas as well as to assess them ergonomically. Therefore it can be concluded that if application of performance oriented anthropometric variables are taken into consideration according to dominant somatotypes, proper designing of sports specific equipments can be done with increased efficiency and minimized occurrence of injury. After statistical analysis, height and arm span are found to have insignificant differences among the three groups of dominant endomorph, mesomorph and ectomorph. So, it can be assumed that proper physical training can minimize the inherent characteristics of individual in respect to height and arm span. Significant difference in total fat mass and lean body mass among the three dominant groups reveals that even in this age range (9-11 years) body composition differs in trained players. It might be concluded that these changes in body composition might be due to their physiologic as well as metabolic demand of the body. It indicates though chronological age and height may not be differing among three dominant somatotypes, but still they differ in body build. From the significant differences observed in weight, hand span, hand length, hand width, cubit length and wrist circumference among three groups, it can be concluded that body type as well as training has an evident impact on these players. Moreover the significant differences in these performance oriented anthropometric parameters among the dominant endomorph, mesomorph and ectomorph reveals the requirement of considering these factors in designing of proper sports equipments for proper fit, comfort and safety.

Therefore this study reveals that though the tennis players (9-11 years) are almost under the same training programmed, but they differ in their body composition, somatotypes and also in most of performance oriented anthropometric parameters.

Table 1: Age (yrs), Height (cm), Weight (kg), Total Fat Mass (kg) and Lean Body Mass (kg) of dominant Endomorph, Mesomorph and Ectomorph of 9 - 11years trained male Tennis players (NS = Not Significant, p = Level of Significance).

Variables	Statistical Analysis	Endomorph [n=6]	Mesomorph [n=9]	Ectomorph [n=6]
Age (years)	Mean ± SD	9.67 ± 1.51	11.22 ± 1.99	10.5 ± 3.56
	F Value	0.74		
	Significance of F	NS		
	Scheffe's F Ratio	-	-	-
	Significance of Scheffe's ratio	-	-	-
Height (cm)	Mean ± SD	148.8 ± 4.83	151.29 ± 15.33	145.18 ± 16.37
	F Value	2.98		
	Significance of F	NS		
	Scheffe's F Ratio	-	-	-
	Significance of Scheffe's ratio	-	-	-
Weight (kg)	Mean ± SD	35.33 ± 4.08	48.33 ± 14.46	32.83±9.79
	F Value	4.28		
	Significance of F	*P*<0.05		
	Scheffe's F Ratio	4.90	6.97	0.15
	Significance of Scheffe's ratio	NS	NS	NS
Total Fat Mass (kg)	Mean ± SD	6.32 ± 1.61	7.28 ± 4.51	1.97 ± 1.30
	F Value	5.27		
	Significance of F	*p*<0.05		
	Scheffe's F Ratio	0.32	9.93	5.56
	Significance of Scheffe's ratio	NS	*P*<0.05	NS
Lean Body Mass (kg)	Mean ± SD	29.02 ± 2.99	41.05 ± 10.40	30.87 ± 8.60
	F Value	4.53		
	Significance of F	*P*<0.05		
	Scheffe's F Ratio	7.30	5.25	0.14
	Significance of Scheffe's ratio	*p*<0.05	NS	NS

Table 2: Hand span (cm), Hand length (cm), Hand Width (cm), Cubit Length (cm), Arm Span (cm) and Wrist Circumference (cm) of dominant Endomorph, Mesomorph and Ectomorph of 9 - 11 years trained male Tennis players (NS = Not Significant, p = Level of Significance).

Variables	Statistical Analysis	Endomorph [n=6]	Mesomorph [n=9]	Ectomorph [n=6]
Hand span (cm)	Mean ± SD	16.68 ± 1.35	19.47 ± 1.56	18.12 ± 1.64
	F Value	6.05		
	Significance of F	*p*<0.05		
	Scheffe's F Ratio	28.02	2.82	2.67
	Significance of Scheffe's ratio	*p*<0.05	NS	NS
Hand length (cm)	Mean ± SD	14.43 ± 0.78	17.31 ± 1.76	15.85 ± 2.30
	F Value	5.00		
	Significance of F	*p*<0.05		
	Scheffe's F Ratio	9.89	2.54	2.00
	Significance of Scheffe's ratio	*p*<0.05	NS	NS
Hand Width (cm)	Mean ± SD	16.02 ± 0.79	18.28 ± 1.76	16.42 ± 2.01
	F Value	4.17		
	Significance of F	*p*<0.05		
	Scheffe's F Ratio	6.86	4.65	0.18
	Significance of Scheffe's ratio	NS	NS	NS
Cubit Length (cm)	Mean ± SD	36.08 ± 0.79	42.42 ± 4.95	39.17 ± 4.94
	F Value	4.11		
	Significance of F	*p*<0.05		
	Scheffe's F Ratio	8.11	2.13	1.60
	Significance of Scheffe's ratio	*p*<0.05	NS	NS
Arm Span (cm)	Mean ± SD	133.82 ± 2.96	154.26 ± 17.20	143.77 ± 18.02
	F Value	3.41		
	Significance of F	NS		
	Scheffe's F Ratio	-	-	-
	Significance of Scheffe's ratio	-	-	-
Wrist Circumference (cm)	Mean ± SD	13.65 ± 0.68	15.86 ± 1.88	13.75 ± 1.76
	F Value	4.65		
	Significance of F	*p*<0.05		
	Scheffe's F Ratio	6.84	6.24	0.01
	Significance of Scheffe's ratio	NS	NS	NS

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