Original Article

Relationship between anthropometric parameters with vertical jump in male elite volleyball players due to game's position

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ABSTRACT

Fattahi A, Ameli M, Sadeghi H, Mahmoodi B. Relationship between anthropometric parameters with vertical jump in male elite volleyball players due to game's position. *J. Hum. Sport Exerc.* Vol. 7, No. 3, pp. 714-726, 2012. Recent study was performed to determine relationship between anthropometric properties with vertical jump on 40 male elite volleyball players (27.93±3.92 years old and 8±1.53 years sport history) in Iran premier league. 42 anthropometric parameters were measured using caliper and flexible tape meter (JAMAR STAINLESS®). In order to decrease parameters covering the same measurements among 42 anthropometric properties, multiple correlation were applied and parameters with coefficient higher than 0.8 were selected for further analysis, so number of parameters decreased to 17. Using principle component analysis method on 17 parameters, three main components including 70% of data variance were extracted. In the main components, parameters with coefficient more than 0.7 including weight, seated height in fixture, shank length, foot length, torso circumference at hip level, maximum calf circumference, abdomen fat, middle tight circumference and tight length were used for further analysis. The difference in distance between the standing reach height and the jump height was measured as the vertical jump records. To determine differences between vertical jump records and also relationship between anthropometric properties with vertical jumps, one way variance analysis (F- Test) and regression coefficients were used. There are significant differences between vertical jump of spikers and liberos, also between setters and liberos, but there are no significant differences between vertical jump of spikers and setters. There is significant relationship between vertical jumps with shank length, maximum calf circumference, foot length for spikers and setters, also tight circumference and weight for liberos. **Key words**: ANTHROPOMETRY, PHYSICAL FITNESS, VOLLEYBALL.

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INTRODUCTION

Anthropometric properties of athletes represent important prerequisite for successful presence at the same sport, effecting athlete's performance and are necessary in order to gain excellent performance of sports skills (Bayois et al., 2006; Duncan et al., 2006; Gualdi-Rosso & Zaccogni, 2001; Ibrahim, 2010). It is assumed special sports' success is directly related to athlete's anthropometric characteristics of the same sport (Bayois et al., 2006; Catagay et al., 2008; Gualdi-Rosso & Zaccogni, 2009; Malousaris et al., 2008).
Volleyball, as one of the most amazing sports, includes fast movements, jumpings, landings and sudden shifts which need high power and strength for optimized performance (De almeida & Soarres, 2003). Physical structures of volleyball players are mainly assessed through measuring anthropometric parameters such as standing height, Body mass index and some other physical factors related to performance skills like jumping ability, agility, strength and endurance (Bayois et al., 2006; Duncan et al., 2006; Gualdi-Rosso & Zaccogni, 2001; Ibrahim, 2010; Palao et al., 2008; Zhang, 2010). Numerous studies have investigated anthropometric parameters of volleyball players, demonstrating higher standing height and lean muscle mass, lower seated height, longer hands, thinner hip and ankle, thicker shin, longer Achilles tendon and longer lower extremity are the most important ones (Bayois et al., 2006; Catagay et al., 2008; De Almeida & Soares, 2003; Duncan et al., 2006; Gabbet & Gorgieff, 2007; Gualdi-Rosso & Zaccogni, 2001; Ibrahim, 2010; Jin et al., 2007; Malousaris et al., 2008; Paolo et al., 2008; Zhang, 2010; Xing et al., 2006). Beside physical ability, muscle strength and power, agility, flexibility, individual techniques and teamwork capabilities, anthropometric parameters are effective in success of volleyball players (Bayois et al., 2006; Ciccarone et al., 2007; Duncan et al., 2006; Zhang, 2010). In many investigations, volleyball is introduced as a power sport in which optimized performance of players are mainly related to the amount of jumping (Ciccarone et al., 2007; Gualdi-Rosso & Zaccogni, 2001; Ibrahim, 2010; Malousarisa et al., 2008; Stamm et al., 2003; Strangelli et al., 2008; Voigt & Vetter, 2003; Xing et al., 2006). One of the main purposes of volleyball players in a match is superiority on the net against the other team and players with higher jumping ability have the advantage comparing to the others (Ciccarone et al., 2007). Lower extremity power and vertical jumping are of the significant indexes of volleyball players to be successful (Stec & Smulsky, 2007).

Usually in a volleyball game, Attack and Block skills constitute approximately 45% of total movements and reflexes and almost 80% of points are gained through these techniques (Voigt & Vetter, 2003). Better performance of spike and Block as well as jumping service are dependent to the amount of height which players can reach (Ciccarone et al., 2007). Studies show that there is significant correlation between vertical jump ability with success rate of spike and block in volleyball games (Xing et al., 2006). One of the most important purposes of training is improving muscle strength and power for volleyball players (Voigt & Vetter, 2003; Hertogh & Hue, 2002). Volleyball players' excellent performances are widely associated with efficiency of jumping or lower extremity explosive power which finally introduce vertical jump as one of the most important characteristics of physical fitness in volleyball players (Zhang, 2010). Like other power sport, muscle power seems to be a vital component for volleyball players (Hertogh & Hue, 2002). Relationships between anthropometric parameters with physical performance of volleyball players have been studied in some investigations. Palao et al. (2008) reported that beach volleyball players' anthropometric parameters are smaller comparing to the gym volleyball players one. Results of Ciccarone et al. (2007) showed that there is significant relationship between anthropometric parameters and game's position with biomechanical properties of volleyball players. Stamm et al. (2003) reported that anthropometric parameters have significant effect on performing of all technical and tactical components especially Block and Spike. You (2003) reported hands length have significant correlation with technical skills of volleyball during ball contact phase (You & Huang, 2002). Ling et al. (2007) reported that waist circumference has negative correlation with function of abdominal muscles in volleyball players. Duncan et al. (2008) showed that seated height to standing height ratio is considered as an effective scale on center of mass which has positive effects on agility and fast movement but negative factor for jumping ability. Voight et al. (2003) reported that hands muscle strength has positive relationship with velocity of hands' twisting and finally consequent force transmitted to the ball.

Zhang (2010) assessed anthropometric profiles of Chinese elite volleyball players and their relationships with physical features but no relationships were derived. Davis et al. (2003) studied predictor factors which determine vertical jumping and physical parameters of amateur athletes and no significant relationship between some anthropometric parameters such as fat, lower extremity length with jumping ability.

Purpose of this study is to determine relationship between anthropometric parameters with vertical jump of male elite volleyball players of Iran.

MATERIAL AND METHODS

Recent study was performed to determine relationship between anthropometric properties with vertical jump on 40 male elite volleyball players (27.93±3.92 years old and 8±1.53 years sport history) which at least played for 4 years in Iran premier league. Individual satisfaction and information forms were completed by subjects in the players' residence in national team camp in addition to describing purposes and necessities of this study. 42 anthropometric parameters (presented in Appendix) were measured using caliper and flexible tape meter (JAMAR STAINLESS®). In order to decrease parameters covering the same measurements among 42 anthropometric properties, multiple correlation were applied and parameters with coefficient higher than 0.8 were selected for further analysis, so number of parameters decreased to 17. Using principle component analysis method on 17 parameters, three main components including 70% of data variance were extracted. In the main components, parameters with coefficient more than 0.7 including weight, seated height in fixture, shank length, foot length, torso circumference at hip level, maximum calf circumference, abdomen fat, middle tight circumference and tight length were used for further analysis. Measuring Vertical jump was done according to Sargent Standard Test as described below. First, confidence of appropriate physical condition were achieved, correct process of measurement were described for them and then subjects warmed up completely to perform the test. Subject stands side on to a wall and reaches up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips is marked or recorded. This is called the standing reach height. The athlete then stands away from the wall, and jumps vertically as high as possible using both arms and legs to assist in projecting the body upwards. Attempt to touch the wall at the highest point of the jump. The difference in distance between the standing reach height and the jump height is the score. The best of three attempts is recorded. After gathering vertical jump's data, subjects divided to three separate groups according to their game's position including spikers, setters and liberos. To determine differences between vertical jump records of spikers, setters and liberos one way variance analysis (F- Test) was used, also, in order to determine relationship between anthropometric properties with vertical jumps regression coefficients were used between derived parameters from principle component analysis and vertical jump records in different groups.

RESULTS

Among the subjects, 25% were setters, 50% were spikers and 25% were liberos.

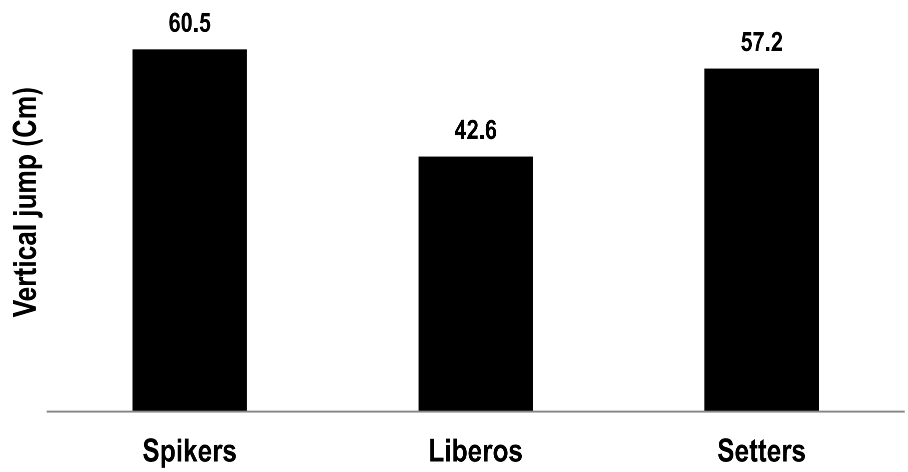

Figure 1. *Mean Averages of Vertical jumps due to game's position.*

According to the Figure 1, spikers and liberos have the highest and the lowest vertical jump, respectively. Figure 2 shows variance percentage of components derived from component analysis. Totally, three main extracted components include 70% of total information variance.

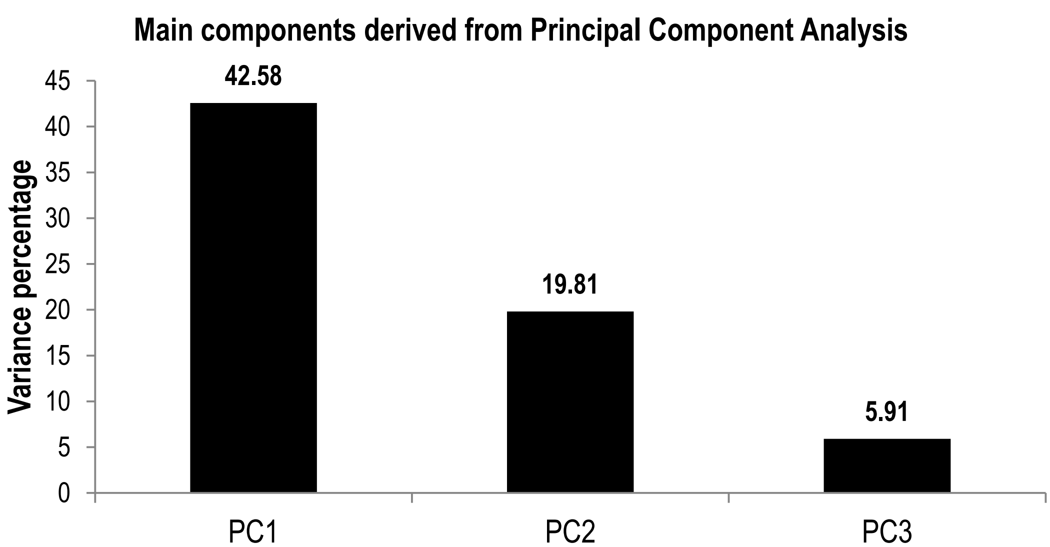

Figure 2. *Variances percentage of extracted parameters from principle component analysis.*

Table 1 show coefficients resulted from principal components analysis of extracted parameters.

Table 1. *Coefficients of extracted parameters from triple components using principle components analysis.*

PC1	PC2	PC3
Shank length (0.91)	Abdomen fat (0.88)	Tight length (0.75)
Seated height in fixture (0.89)	Maximum calf circumference (0.82)	--
weight (0.85)	Middle tight circumference (0.79)	--
Foot length (0.82)	--	--
Torso circumference at hip level (0.81)	--	--

According to Tables 2 and 3 there are significant differences between vertical jump of spikers and liberos, also between setters and liberos, but there is no significant difference between vertical jump of spikers and setters. Differences seem to be logical and explainable according to the game's position and duty of players in various positions.

Table 2. *Results of one way variance Anova-analysis of subjects' vertical jumps.*

	Sum of squares	Df	Squares average	F	Sign.
Between Groups	2204.05	2	1102.03		
Within groups	3256.45	37	88.01	12.52*	2.34
Total	5460.5	39	140.01		

**Significant differences p<0.05*

Table 3. *Results of Scheffe Tests according to game's position.*

	Scheffe Score	Sign.
Spikers jump--------Setters jump	1.64	2.16
Spikers jump--------Liberos jump	7.97*	2.16
Setters jump--------Liberos jump	6.54*	2.16

Tables 4, 5, 6 show results of regression coefficients between extracted parameters from Principal Component Analysis and vertical jump of subjects in different games' positions.

According to Table 4, estimated equations between vertical jump and anthropometric parameters extracted from principal component analysis for Volleyball players according to their game's position are presented as:

Vertical jump records (for Spikers) = $27.31 + 0.42X_1 – 0.13X_2 – 0.39X_3 + 0.98X_4 – 0.05X_5 – 3.34X_6 + 0.03X_7 + 0.43X_8 + 0.26X_9$

Vertical Jump records (for Setters) = $14.33 + 26.07X_1 - 7.04X_2 - 9.3X_3 + 15.02X_4 + 2.64X_5 - 17.25X_6 + 10.92X_7 + 0.24X_8 - 10.17X_9$

Vertical jump records (for Liberos) = $-61.94 + 2.29X_1 + 0.27X_2 - 1.58X_3 + 1.31X_4 + 1.22X_5 + 3.14X_6 - 1.30X_7 + 2.39X_8 - 1.55X_9$

In which:
X_1: Foot length, X_2: Seated height in fixture, X_3: Weight, X_4: shank length, X_5: torso circumference at hip level, X_6: abdomen fat, X_7: Maximum calf circumference, X_8: middle tight circumference, X_9: tight length

Table 4. *Regression coefficients (β) between anthropometric parameters and vertical jump of male elite Spikers.*

Spikers parameters	Unstd. Coefficients		Std. Coefficients
	Beta	**Std. Error**	**Beta**
Constant	27.31	58.54	--
Foot length	0.42	2.79	0.08
Seated height in fixture	-0.13	0.46	-0.12
Weight	-0.39	0.53	-0.57
Shank length	0.98	0.64	0.69
Torso circumference at hip level	-0.05	0.67	-0.37
Abdomen fat	-3.34	3.79	-0.33
Maximum calf circumference	0.03	1.2	0.54
Middle tight circumference	0.43	0.48	0.43
Tight length	0.26	0.45	0.21

Table 5. *Regression coefficients (β) between anthropometric parameters and vertical jump of male elite Setters.*

Setters parameters	Unstd. Coefficients		Std. Coefficients
	Beta	**Std. Error**	**Beta**
Constant	14.33	0.00	--
Foot length	26.07	0.00	7.92
Seated height in fixture	-7.04	0.00	-4.77
Weight	-9.3	0.00	-10.97
Shank length	15.02	0.00	7.92
Torso circumference at hip level	2.64	0.00	1.55
Abdomen fat	-17.25	0.00	-1.42
Maximum calf circumference	10.92	0.00	8.10
Middle tight circumference	0.24	0.00	0.22
Tight length	-10.17	0.00	-5.30

Table 6. *Regression coefficients (β) between anthropometric parameters and vertical jump of male elite Liberos.*

Liberos parameters	Unstd. Coefficients		Std. Coefficients
	Beta	Std. Error	Beta
Constant	-61.94	0.00	--------
Foot length	2.29	0.00	0.45
Seated height in fixture	0.27	0.00	0.35
Weight	-1.58	0.00	-1.36
Shank length	1.31	0.00	0.57
Torso circumference at hip level	1.22	0.00	0.66
Abdomen fat	3.14	0.00	0.23
Maximum calf circumference	-1.30	0.00	8.10
Middle tight circumference	2.39	0.00	1.19
Tight length	-1.55	0.00	-0.65

The most important parameters affecting on vertical jumps in Spikers are weight, shank length and maximum calf circumferences which weight has negative effect and the others have positive effect on vertical jumps' records of male elite spikers. There is significant relationship between vertical jump with Weight, foot length, Shank length and maximum calf circumference in Setter and finally, in liberos, there is significant relationship between weight, maximum calf circumference and tight length with vertical jump.

Consequently, there is significant relationship between parameters such as weight, shank length, maximum calf circumference, foot length, tight length and vertical jump of male elite volleyball players.

DISCUSSION

Anthropometric properties as well as appropriate physical fitness are important prerequisites for outstanding performance of sports skills and play a distinguished role in sports' successful achievements (Stamm et al., 2003). Thus, physical structures provide a substructure in order to form and improve motor techniques specially various sports' physical performances.

Volleyball, as a power sport, demand high number of jumps for players to perform spikes and blocks, so the ability of jumping is introduced as an important factor determining physical fitness of volleyball players through assessing lower extremity and abdominal explosive power. Results of study are agreement with the results of Davis et al. (2003) and disagreement with Zhang (2010). Davis et al. (2003) demonstrated that there is significant relationship with some anthropometric parameters such as foot length, fat and circumference of some joints, although it was performed on amateur athletes. Maybe one of disagreement's reasons with Zhang (2010) is differences in gender. Zhang's study was performed on Chinese elite athletes. It is remarkable that jumping styles in females and males are different, with greater extension of knee joint and back and lower plantar flexion of ankle in females comparing to males (Rupesh, 2010). According to results, among the extracted anthropometric parameters, weight, shank length, maximum calf circumference, seated height, torso circumference in hip level and tight length are the most significant related parameters with vertical jumping of male elite volleyball players. There is great similarity between effective parameters on vertical jumping of spikers and setters which are not noticeable in liberos. The differences in parameters could be explained through game's position of players. The main purpose of volleyball players is achieving greater height on the net (Stec & Smulsky, 2007). Nowadays players who are able to achieve greater height during performing spike and block, as the most valuable skills in volleyball have the advantages comparing to other players which is possible with the ability of higher jumping (Ciccarone et al., 2007). Liberos as the backline players participate in receive and digging during the match but setters and spikers play in front of the net, performing spike and block (Duncan et al., 2008). It is clear that higher jumping is not advantage for liberos whereas it is necessary for spikers and blockers. Review of table 1 shows that there is significant difference between vertical jumping of liberos with spikers and blockers.

Amount of vertical jump is affected by various physiological and biomechanical parameters (Strangelli et al., 2008). Vertical jump totally is determined through vertical velocity components and gravity during takeoff phase. Jumping process requires an external force as the ground reaction force which is the result of generated torques transmission to the ground. Joint's Torque is generated from muscle contraction during structure displacement. Final torque in a joint is difference of contractile forces in agonist and antagonist muscles. Moreover amount of force is also dependent to muscular properties. Ground reaction force should be greater than weight. Then, it will be transmitted to the body and determine velocity of center of mass (COM). An appropriate vertical jump could be explained through Newton second law, direct dependence of body acceleration with mass and third law, action and reaction law. A vertical jump will exert a reaction force, equal and in the opposite direction, caused by applied force on the ground, called as acceleration of the COM. Vertical jump' performance is determined through displacement magnitude and direction of Com velocity in take off phase and is measured by COM displacement. Finally, consequent of five parameters including velocity, joint angle, COM height, air resistance and gravity force, all in take off phase, will lead to maximum of vertical jump (Rupesh, 2010). But dependence of vertical jump with anthropometric and physical parameters, also, should be noticed. As regression tables show shank length, maximum of calf circumference and weight are as the most important anthropometric parameters affecting vertical jump for spikers and setters. It is remarkable that a high vertical jump requires forces greater than gravity as the negative force, which is advantage for a volleyball player with lower weight comparing to heavy ones. Fat, also, has positive correlation with mass and body weight. More fat causes more body weight that requires greater forces in order to overcome gravity force (Rupesh, 2010; Zhang, 2010). Greater calf circumference has significant correlation with jump in spikers and setters. Muscle size effects force producing and jump performance. Perhaps, greater physiological cross section of muscles, contains more sarcomers contributing in muscular contractile which leads to more cross bridges foundation and finally greater force production. Greater shank length and foot length in jumpers causes a grater torque for a reaction force in ankle joint, consequently more lever length and more transmitted force. Also, greater Achilles tendon and greater produced power in a short or quick .Ratio of seated height in fixture to standing height is determinant of lower extremity to upper extremity. Lower amount of this ratio in volleyball players shows higher lower extremity, longer bones in lower extremity and finally higher COM (De Almeida & Soares, 2003, Duncan et al., 2006; Gualdi-Rosso & Zaccagni, 2009; Malousaris et al., 2008; Zhang, 2010). Higher COM in jumpers is an advantage because it helps them to make more acceleration and force in a longer distance of the body, so by means of displacement, transmission of COM in vertical direction is easier (Rupesh, 2010; Zhang, 2010).

CONCLUSIONS

Maximum vertical jump is one of the necessary components in performing spike and block skills in volleyball. According to the study, there is significant relationship between vertical jumps with Weight, shank length, maximum calf circumference, foot length for spikers and setters, also tight circumference and weight for liberos. However, anthropometric parameters are effective on vertical jumps on different game's position in volleyball players. Considering anthropometric parameters as well as training methods due to game's position seems to be necessary for volleyball players.

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APPENDIX

Anthropometric parameters and instruction[*]:

Weight	Ask the subject to take his/her shoes off. Have the subject stand on the scale facing forward with both feet solidly on the scale and the weight evenly distributed between the feet. Record the subject’s weight in kilograms.
Standing Height	Have the subject stand with his heels together and the weight evenly distributed between both feet. The subject should stand erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor. Take the measurement with an anthropometer from the ground to the highest point on the subject’s head while firmly contacting the scalp. The measurement will be in cm
Standing Acromion Height	Have the subject stand erect with his heels together and weight evenly distributed between his feet. Measure the vertical distance from the Acromion to the floor using an anthropometer
Standing Knee Height	Have the subject stand erect with their heels together and weight distributed evenly between both feet. Locate the patella (knee cap) on the front of the knee and find the center of that bone. Measure the distance from the floor to this location using a caliper
Seated Height in Fixture	Have the subject sit in the test fixture used in the experiment. The feet should be placed on the footrest so that both the thighs and the feet are parallel and lie in the horizontal plane. The subject should sit erect with the Frankfort plane (line passing horizontally from the ear canal to the lowest point of the eye orbit) of his head

	parallel to the floor The measurement is taken with an anthropometer and is measured from the ground to the highest point on the subject's head with the anthropometer arm firmly contacting the scalp (in cm)
Seated Hip Breadth	Measure the lateral distance at the widest part of the hips
Seated Ankle Distance (Horizontal)	Have the subject sit in the industrial chair with their feet positioned comfortably on the footrest. Using a caliper, measure the horizontal distance from L5 to the lateral malleolus
Head Width	Using a spreading caliper, measure the maximum width of the head above the ears
Head Depth	Using a spreading caliper, measure the distance from the nasion (indentation at the top of the nose between the eyes) to the most posterior point on the back of the head
Head Length	Measure the linear distance from the bottom of chin to the highest point (Vertex) on the top of the head.
Head Circumference	Measure with flexible tape. Place tape above ear and across brow. Hold tape firmly to compress hair as much as possible
Two hands distance	distance between tip of left to right of 3rd finger in frontal plan
Torso Width at Nipple Height	Measure the linear distance across the torso at the level of the nipples.
Torso Circumference at Nipple Height	Using flexible measuring tape measure the circumference of the torso at nipple height.
Torso Width at Umbilicus	Measure the linear distance across the torso at the level of the umbilicus
Torso Circumference at Umbilicus	Using flexible measuring tape measure the circumference of the torso at umbilicus level
Torso Width at Hip	Measure the linear distance across the torso at the location of the hip joint centers.
Torso Circumference at Hip	Using flexible measuring tape measure the circumference of the torso at the level of the hip joint centers. Make sure to encircle both lower limbs when performing the measurement
Upper Arm Circumference at Axilla	Using flexible measuring tape, measure the circumference of the upper arm as proximally as is possible
Maximum Upper Arm Circumference	Locate and record the maximum circumference using the flexible measuring tape by measuring along the length of the upper arm
Forearm Length	Have the subject stand with his arms straight at his side with his hands and fingers in line with the forearm. The measurement is taken from the right radiale (identified as the bony process on the outside of the elbow) to the stylion landmark (bone on the thumb side of the wrist)
Elbow Circumference	Using the flexible measuring tape, measure the circumference of the elbow, ensuring that the measuring tape passes through both the medial and lateral epicondyle of the humerus

Maximum Forearm Circumference	Locate the maximum circumference using the flexible measuring tape by measuring along the length of the forearm
Elbow Width	This measurement will be taken using a beam caliper. Have the subject stand with the right upper arm hanging at the side and the elbow flexed at 90 degrees. Make sure the hand is straight and the palm is facing in. While standing behind the subject, measure the distance between the lateral and medial picondyles of the humerus
Wrist Width	With a sliding caliper measure the distance between the outer edges of the wrist. Have the subject place his hand on a table for this measurement
Wrist Circumference	Using the flexible measuring tape, measure the circumference of the wrist, at the same location as wrist width was measured
Hand Length (Wrist to Tip of 3 nd Finger)	Have the subject place his hand on a table with the fingers together and thumb abducted. The measurement is taken with a sliding caliper from the stylion landmark identified above to the tip of the middle finger
Thigh Length	This is measured as the linear distance between the joint centers of rotation of the hip and the knee
Mid-Thigh Circumference	This measurement is taken midway between the hip joint Center and the center of the patella. Once again, use the flexible measuring tape to measure the circumference of the thigh at this location
Femoral Epicondyle (Knee) Width	Have the subject sit on a flat surface so the thighs are parallel and the knees are flexed 90 degrees. Thighs should be straight forward with lower leg straight down forming a 90 ° angle. With a caliper, measure the distance between the medial and lateral right femoral epicondyles (bones on the side of the knee
Knee Circumference	For this measurement use the flexible measuring tape around the knee, using the center of the patella and the posterior knee crease to align the measuring tape
Shank Length	This is measured as the linear distance between the joint centers of rotation of the knee and the ankle
Maximum Calf Circumference	Using the flexible measurement tape, locate the maximum circumference of the calf by moving the tape proximally and distally along the calf
Foot Length	This is measured as the linear distance between the back of the heel and the tip of the second toe.
Foot Arch Circumference	Measure the circumference of the foot halfway between the ankle joint and the ball of the foot using the flexible measuring tape
Malleolus Width	Have the subject stand erect with both feet firmly on the ground and slightly apart. Measure the horizontal distance between the two anklebones with a caliper
Triceps fat	On the back of the right arm over the triceps muscle, midway between the elbow and the acromion process of the Scapula. Pinching the fold slightly and using a caliper, triceps skinfold is measured
Subscapular fat	The lower angle of the scapula (bottom point of shoulder blade). The pinch is made following the natural fold of the skin, approximately on a line running laterally

	(away from the body) and downwards (at about 45 degrees).
Calf fat	Is measured on the inside of the right leg at the level of maximal calf girth. The right foot is placed flat on an elevated surface with the knee flexed at a 90°. The vertical skin fold should be grasped just above the level of maximal.
Tight fat	The mid-point of the anterior (front) surface of the thigh, midway between patella (knee cap) and inguinal fold (crease at top of thigh). The mid-point of the anterior (front) surface of the thigh, midway between patella (knee cap) and inguinal fold (crease at top of thigh).
Abdomen fat	Is measured at a site 3 centimeters to the side of the midpoint of the umbilicus and 1 centimeter below it. The skinfold is horizontal and should be measured on the right side of the body. The subject relaxes the abdominal wall as much as possible.
Suprailiac fat	Immediately above the iliac crest (top of hip bone), on the most lateral aspect (side). The fold is directed anterior and downward in line with the natural fold of the skin. The right arm should be held across the body to keep it away from the measurement area

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