Height Estimation Using Anthropometric Measurements On X-Rays Of Wrist And Metacarpal Bones

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Citation

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Abstract

The aim of our study is to estimate of height from wrist radiograms. The wrist radiograms was taken from 100 healthy individuals in Ankara University Radiology Department and Orthopedics Department Hand Surgery Clinic between September 2005 and September 2006. For a common formula for the entire population, R=0.990 (correlation between the predicted value and observed values) was found between body mass index, width of the hand, width of the 3rd metacarpal, length of hand, age, width of 2nd metacarpal, length of 3rd metacarpal, body weight, and length of 2nd metacarpal, and multiple coefficient of determination (degree of explanation of the dependent variable by the independent variable) was calculated as R2= 0.9616. It was found that the fixed value and coefficients of height, length of the hand, and mass index were important. In conclusion, variables were selected with stepwise regression analyses, and accordingly, 5 regression models were established to calculate height.

INTRODUCTION

One of the questions when people find new remnants of the skeleton is "what was the height of this person when he was alive?" For this information, which is one of the most important issues for identification, forensic medicine specialists and forensic anthropologists have taken interest since a long time in determining the height from dimensions of bones.

It is possible to determine the height of a dead body by two methods defined as anatomical and mathematical methods. The mathematical method, which is one of the most frequently used one nowadays, is the method for calculating the height by considering the mathematical regression coefficients obtained from the measurements of many bones of the body [1] . Trotter and Gleser [2,3] , who contributed much to the establishing and developing of the mathematical method and that the use of equations they established still continues in our days also, studied particularly the American population, and made comparisons among various groups in this population with different structures. The basic principle of Trotter and Gleser equations is the comparison of the measured part of the skeleton to the equivalent in living individuals or cadavers [2,3] . Telkka [4,5] showed that lengths of humerus, radius, ulna, femur, tibia and fibula could be used in calculating the heights of Finnish children with acceptable accuracy.

When we look at the literature of the recent years, we see that Abrahamyan et al [6] have measured height using whole-body dual energy X-ray absorptiometry scans in humerus, radius, femur and tibia measurements in children; Bidmos [7] from seven anthropometric measurements taken from the femur, including the maximum length of the femur, Krishan [8] with measurements on footprints and contours of the feet, Krishan and Kumar [9] with cephalo-facial measurements, Giroux and Wescott [10] from the pelvic bone and proximal femur, and Krishan and Sharma [11] from hand and foot dimensions.

Determining the height by anthropometric measurements of metacarpal and wrist bones and radiological evaluation becomes important in natural disaster, mass deaths and in disintegrated bodies where long bones cannot be found. Therefore, it was aimed at establishing height regression formulas by taking the metacarpal measurements anthropometrically in radiograms for individuals living in Turkey, and developing the basic knowledge of identification process.

MATERIAL AND METHODS

In this study, decision was made for taking wrist radiograms of individuals who presented in Ankara University

Radiology Department and Orthopedics Department Hand Surgery Clinic between September 2005 and September 2006 with various complaints, who had no somatic diseases that would hinder their development according to their height and body weight, and particularly without any signs of a disease or trauma, after their physical examination and obtaining their informed consent. Cases participating in the study were asked to fill a preliminary questionnaire about demographic characteristics like age, place of residence, place of birth, and occupation before taking the x-rays. Heights and body weights of the cases were measured, and takes of radiograms were started after calculating the BMI (Body Mass Index) values. X-rays of left wrists were taken from a distance of 155cm in P-A (posteroanterior) projection using the same radiography device featuring 1,9 MAS and 48 KW by the same technician.

Because of the requirement of making the radiological examination after completion of the skeletal development, the lower age limit of the study was determined as 20 years of age. 46 females and 54 males were examined.

The wrist x-rays taken were imaged with a digital camera according to scale, and were recorded to be exported to a suitable computer program. Measurements were taken from the x-rays exported to a computer using Konika 2006 MERGE eMED program. The feature of this program is to allow the anthropometric measurements of normal hand and metacarpal bones of the individuals with millimetric precision on the radiograms. Anthropometric measurement results according to Martin technique on the radiograms taken in radiodiagnostic position of left hand are listed below ; [12,13,14,15]

Hand length: Distance between the midpoint of the line connecting the distal styloid points of radius and ulna (midpoint of plica carpalis distalis) and foremost point of the middle finger.

Hand width: Distance between the metacarpophalangeal joints II-V.

Length of the third metacarpal: Distance between the most protuberant point of the third metacarpal and the midpoint of the line in the carpo-metacarpal space.

Width of the third metacarpal: Perpendicular distance to the line passing through the midpoint of the third metacarpal from the two foremost points of the metacarpal.

Length of the second metacarpal: Distance between the most protuberant point of the second metacarpal and the midpoint of the line in the carpo-metacarpal space.

Width of the second metacarpal: Perpendicular distance to the line passing through the midpoint of the second metacarpal from the two foremost points of the metacarpal.

Statistical evaluation was performed using SPSS 11.5 for Windows statistical package program. One-way analysis of variance (ANOVA) was used for the evaluation of each parameter. Correlation and regression analyses were used to undisclose the relationship between the variables and to obtain the unknown variable using the known variable.

RESULTS

In our study, 46 (%46) of 100 cases were females, and 54 (54%) were males, and there were no statistically significant differences between the groups as regards gender ($p<0.05$). While average age of females was 30.98 ± 10.277, and average age of males was 29.98 ± 8.786, the average of the entire group was 30.44 ± 9.465; the youngest being 20 years of age and the oldest 69. While birth places of 68% cases were in Middle Anatolia region, individuals born in Black Sea (16%), Marmara (6%), Eastern Anatolia (4%), Aegean (3%), Southeastern Anatolia (2%) and Mediterranean (1%) regions were also included in the study.

The average body mass index of the cases was found as 24.2630 ± 4.07985, minimum being 18.50, and maximum 30.90. Distribution of body mass index according to gender is given in Table 1.

Figure 1

Table 1: Distribution of height measurements in genders

Height (Cm)	Female		Male		Total	
	n	%	n	%	n	%
151	-	-	1	1,8	1	1
155	2	4,3	-	-	2	2
156	1	2	-	-	1	1
157	3	6,5	-	-	3	3
158	2	4,3	-	-	2	2
160	10	21,7	1	1,8	11	11
161	1	2	-	-	1	1
162	1	2	1	1,8	2	2
163	5	11	-	-	5	5
164	-	-	1	1,8	1	1
165	7	15	-	-	7	7
166	1	2	1	1,8	2	2
167	3	6,5	-	-	3	3
168	4	8,6	3	5,5	7	7
169	-	-	2	3,6	2	2
170	-	-	3	5,5	3	3
171	1	2	1	1,8	2	2
172	-	-	3	5,5	3	3
173	3	6,5	4	7,4	7	7
174	-	-	1	1,8	1	1
175	-	-	7	12,7	7	7
176	1	2	2	3,6	3	3
177	-	-	1	1,8	1	1
178	1	2	3	5,5	4	4
180	-	-	7	12,7	7	7
181	-	-	1	1,8	1	1
182	-	-	2	3,6	2	2
183	-	-	4	7,4	4	4
185	-	-	1	1,8	1	1
186	-	-	2	3,6	2	2
189	-	-	1	1,8	1	1
195	-	-	1	1,8	1	1
TOTAL	46	100	54	100	100	100

Average height was found as 163.67 ± 5.582 cm for females, and 175.44 ± 7.588 cm for males (Table 2). Average height for the entire group was 170.03 ± 8.902 cm, and minimum height was 151 cm, and maximum 195.

Figure 2

Table 2 : BMI index distribution related to gender

BMI (kg/m^2)	Female		Male		Total	
	n	%	n	%	n	%
18,5-23,9	29	62,94	24	44,4	53	53
24-29,9	13	28,36	24	44,4	37	37
30-30,9	4	8,6	6	11,2	10	10
Total	46	100	54	100	100	100

Differences in study variables according to height were examined with Pearson's correlation test. Significant positive correlations were found between height and length of hand (r=0.782), with the length of third metacarpal (r=0.743), and length of second metacarpal (r=0.785). Significant positive correlations were found between the length of hand and the length of third metacarpal (r=0.880) and length of second metacarpal (r=0,894). Positive correlation was found between the lengths of third metacarpal and the second metacarpal (r=0.973). Positive correlation was found between body mass index and weight (r=0.852) (Table 3).

Regression analyses were performed for the estimation of height for females and males. Stepwise methods were used for regression analyses. One linear model was found for females (Fig. 1). Six linear models were found for males, and the most reliable method selected was model 6.

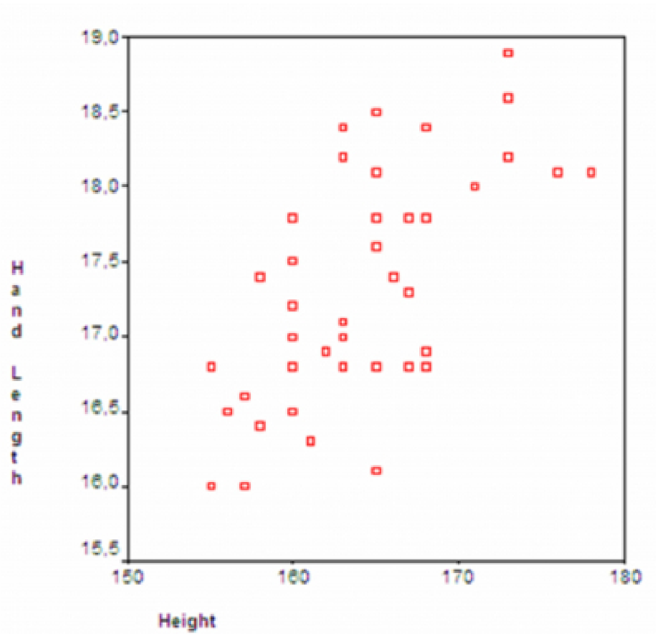
Figure 3

Table 3 : Correlation of variables (MTC : Metacarpal, * p

	Height	Weight	Hand lenght	Hand width	3.MTC length	3.MTC width	2.MTC length	2.MTC width	BMI	Age
Height	1	0,559 (**)	0,782 (**)	0,628 (**)	0,743 (**)	0,333 (**)	0,785 (**)	0,360 (**)	0,050	-0,156
Weight	0,559 (**)	1	0,457 (**)	0,628 (**)	0,446 (**)	0,323 (**)	0,446 (**)	0,431 (**)	0,852 (**)	0,260 (**)
Hand lenght	0,782 (**)	0,457 (**)	1	0,687 (**)	0,880 (**)	0,368 (**)	0,894 (**)	0,410 (**)	0,073	0,025
Hand width	0,628 (**)	0,628 (**)	0,687 (**)	1	0,672 (**)	0,414 (**)	0,664 (**)	0,471 (**)	0,357 (**)	0,093
3.MTC length	0,743 (**)	0,446 (**)	0,880 (**)	0,672 (**)	1	0,382 (**)	0,973 (**)	0,401 (**)	0,079	-0,034
3.MTC width	0,333 (**)	0,323 (**)	0,368 (**)	0,414 (**)	0,382 (**)	1	0,376 (**)	0,386 (**)	0,180	0,208 (*)
2.MTC length	0,785 (**)	0,446 (**)	0,894 (**)	0,664 (**)	0,973 (**)	0,376 (**)	1	0,415 (**)	0,052	-0,046
2.MTC width	0,360 (**)	0,431 (**)	0,410 (**)	0,471 (**)	0,401 (**)	0,386 (**)	0,415 (**)	1	0,300 (**)	0,265 (**)
BMI	0,050	0,852 (**)	0,073	0,357 (**)	0,079	0,180	0,052	0,300 (**)	1	0,414 (**)
Age	-0,156	0,260 (**)	0,025	0,093	-0,034	0,208 (*)	-0,046	0,265 (**)	0,414 (**)	1

Figure 4

Figure 1: Hand length versus height measurements of females



In the regression analyses performed for females, the multiple correlation coefficient between height and the length of hand was found to be R=0.662 and multiple determination coefficients to be R2=0.438.

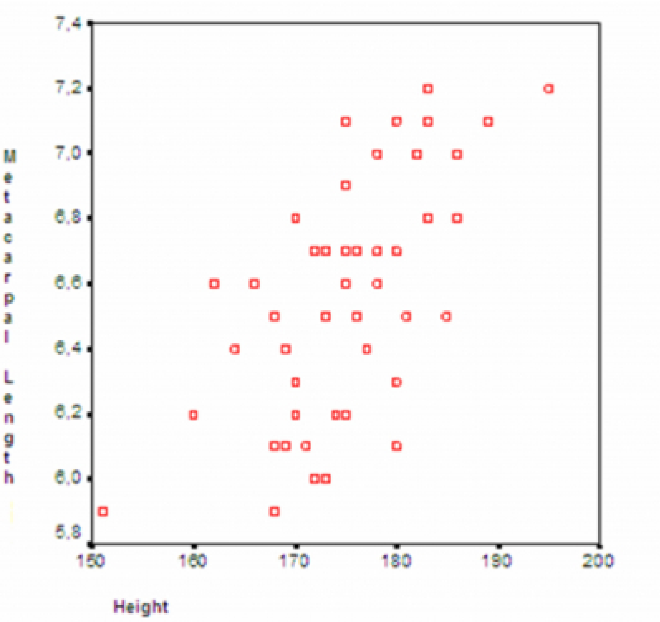
Height for females = 81.950 + 4.729 x length of hand ± 4,154

In the regression analyses performed for males, six different regression models (regression formulas) were estimated. While the first of these was the weakest one because of the standard deviation of 5.965, the sixth one is the best model with a standard deviation of 0.807.

Multiple correlation coefficient for the first model was found as R=0.627 and multiple determination coefficient as R2=0.394 (Fig. 2).

Figure 5

Figure 2: Metacarpal length versus height measurements of males



Height = 90.154 + 12.917 x length of second metacarpal ± 5.965

Multiple correlation coefficient for the second model was found as R=0.685 and multiple determination coefficient as R2=0.469;

Height = 86.153 + 11.563 x length of second metacarpal + 0.169x body weight ± 5.639

Multiple correlation coefficient for the third model was found as r="0.993" and multiple determination coefficient as r2="0.985;

Height = 170.784 + 0.782 x length of second metacarpal + 1.109 x body weight -3.434 x body mass index ± 0.950

Multiple correlation coefficient for the fourth model was found as R=0.993 and multiple determination coefficient as R2=0,987;

Height =165.199 – 0.028 x length of second metacarpal + 1.100 x body weight – 3.410 x body mass index + 0.591 x length of hand ± 0.914

Multiple correlation coefficient for the fifth model was found as R=0,993 and multiple determination coefficient as R2=0,987;

Height =165.170 + 1.099 x body weight – 3.409 x body mass index + 0.582 x length of hand ± 0,904

Multiple correlation coefficient for the sixth model was found as R=0.994 and multiple determination coefficient as R2=0.988;

Height = 168.276+1.114x body weight - 3.416 x body mass index + 0.689x length of hand -0.805 x width of hand ± 0.870.

When a common formula for the entire population is considered, R=0.990 (correlation between the predictive value and observed values) was found between body mass index, width of hand, width of third metacarpal, length of hand, age, width of second metacarpal, length of third metacarpal, weight, and length of second metacarpal, and the multiple determination coefficient (amount of explanation of the independent variable by the dependent variable) was found as R2 = 0.9616. It was found that the fixed value and coefficients of height, length of the hand, and mass index were important. In conclusion, variables were selected with stepwise regression analyses, and accordingly, 5 regression models (regression formulas) were established to calculate height. While the first of these models constituted the weakest model with a standard deviation of 5.546, the fifth model is the best model with a standard deviation of 1.310.

Multiple correlation coefficient for the first model is R = 0.785 and multiple determination coefficient is R 2 = 0.612.

Model 1:

Height =74.312 + 15.140 x length of second metacarpal ± 5.546

Multiple correlation coefficient for the second model is R = 0.819 and multiple determination coefficient is R 2 = 0.664.

Model 2:

Height =76.947 + 12.8990 x length of second metacarpal 2 + 0.165 x body weight ± 5.162

Multiple correlation coefficient for the third model is R = 0.989 and multiple determination coefficient is R 2 = 0.977.

Model 3:

Height =161.255 + 1.219 x length of second metacarpal +1.128 x body weight -3.229 x body mass index ± 1.343

Multiple correlation coefficient for the fourth model is R = 0.989 and multiple determination coefficient is R 2 = 0.978.

Model 4:

Height = 156.552 + 0.109 x length of second metacarpal + 1.113 x body weight -3.189 x body mass index + 0.656 x length of hand ± 1.316

Multiple correlation coefficient for the fifth model is R = 0.989 and multiple determination coefficient is R 2 = 0.978.

Model 5:

Height = 156.595 + 1.114 x body weight – 3.193 x body mass index + 0.692 x length of hand ± 1.310

Whether the relation between the variables was linear or not was tested with ANOVA test. A linear relation according to F value with $p<0.05$ was accepted as statistically significant.

DISCUSSION AND CONCLUSIONS

Identifying of remnants of bodies is a rather important issue in forensic medicine. Studies are being performed with the purpose of determining the gender, height, and age of the remnant found for identification.

Estimation of height with mathematical method, which is one of the most frequently used methods today, is the method of estimating height by taking the mathematical regression coefficients obtained through the measurements of various bones of the body, and particularly the long bones [1,12,13,14,15,16] . Attempts for estimation of height have been performed by developing regression formulae from the long bones of the body [6,10,17] sacrum and coccyx [18] , talus and calcaneus [19] , metacarpal bones [20,21] metatarsal bones [21,22] scapula [23] , vertebrae [24,25] , cranial measurements [9] , and hand and feet measurements [8,11] .

In our study also, mathematical method was used to develop height regression formulas using measures of second and third metacarpals for individuals living in Turkey. Since the calculated heights are unique for the populations examined, as one of the important difficulties of this method, and cannot be used outside that population [20,26,27] our data are also unique for the individuals living in Turkey.

Another problem in using the classical mathematical method is the claim that regression equations give more erroneous results for taller and shorter individuals [3,28] . Therefore, researchers have suggested the use of equations special for height groups rather than the general formula of the classical mathematical method [28,29] . However, this was not used in our study.

It is known that nutritional conditions affect the development of individuals in every aspect [30,31] . When considered from this point of view, hand, metacarpal, height and weight measures are also affected. Although our study group consisted of individuals with middle socio-economical level, since we do not know their living conditions since their birth, we believe that larger and more comprehensive studies are required for any comment on this point.

It was seen that the distribution of our study group focused on the Middle Anatolia region, and was insufficient for the other regions. The main reason for this is that the study was performed within the borders of Ankara province. We think that what kind of differences measures of hand, metacarpals, height and weight display according to regions can be determined with a study including a group distributed among regions proportionally.

Second metacarpal bone is the one with the greatest length among other metacarpal bones and the one with the biggest proximal end except for the 1 st metacarpal. Researchers have shown that the height determination from the 2 nd metacarpal gives as good results as those determined from long bones [20,32] .

Number of subjects in our study population is 100. Minimum height in the population is 151 cm and maximum is 195 cm, and the difference in between is 44 cm. Such a large range of height and lack or cumulating in a certain range of height causes increase in the standard error of the height estimation equation established. However, we agree that the number of subjects should be as large as possible to keep the error emphasized by investigators in a minimum [1]. Together with this, Karl Pearson [33] have emphasized that number of subjects should be between 50 and 100 when similarities between subjects are high in number, and about a few hundred when similarities are weak. However, since we used radiography method with a high cost, our number of subjects was limited.

Distribution of age in the sample group is an important factor because of atrophy seen in bones with aging and considered are physiological within certain limits. Since eighty-seven percent of the cases in our study were within 24-40 age group, homogeneity can be talked of, although not complete.

Himes [34] estimated heights of 710 children (388 girls and 372 boys) from Guatemala with ages varying between 1 and 7 in 1977 from the radiographic lengths of second metacarpal with a standard error of ±3.99 cm, and it was suggested that these formulas could be used in forensic medicine since this standard error was approximately the same with those found from measurements of long bones in adults. Telkka [4,5] estimated height from metacarpals in children from Helsinki in a group consisting of 3848 children younger than 15 years of age. He was able to estimate height in this study with a standard error of ±3.90 cm. In a study performed on 103 child cadavers, it was possible to estimate height from second metacarpals with a standard error of ±5.10 cm [2] and in another one from second metacarpals on Japanese children between 6 and 20 years of age with a standard error of ±4.29 cm. [35]. We believe that comparing these studies with ours that was performed on adults is not appropriate, since these were studies performed on age groups that the development of bones still go on. These were cited here only to stress how studies on second metacarpals diversify according to age groups.

It was reported inn a study performed on 166 university students living in Upper Egypt that height estimation was performed with a standard error of ±5 cm. [36]. Jindal et al. [37] estimated height from hand measurements in Jats and Banias populations in Punjabi region of India, with a standard error of ±4.69 cm in Jats population and ±4.43 cm standard error in Banias population. Although it was not possible in our study to obtain a formula that could be established from hand measurements only, the most reliable formula among those found was the fifth one using body mass index together with hand measurements as variables, and standard deviation is ±1.31. This is a rather reliable result when compared to other studies. Although the margin of standard error (±5.546) in our first formula obtained by only the measurements of the second metacarpal has the highest standard error among other we have established, this value is comparable to the standard errors of other studies. In addition, differences between populations should also be considered here.

When height regression formulas are calculated separately for two genders, one single formula was established for females since height of women did not show a wide distribution.

Meadows and Jantz [38] performed height estimation with a standard error of ±5.15 in their height estimation from second metacarpals of white and black males in Terry collection.

Musgrave and Harneja [39] performed height estimation with a standard error of ±5.84 in their height estimation from second metacarpals of males aged between 17 and 87 in England in 1978.

Height was estimated with a standard error of ±6.92 cm in the height estimation of Kimura [32] in 1991 on Japanese cadavers of 30 to 92 years, and with a standard error of ± 3,80 cm in another estimation performed on 100 males from Punjabi with hand measurements [13].

Özaslan [12] established the regression formulas given below in his study he estimated height from measurements of second metacarpal on 184 male cadavers lived in Turkey, and suggested that the margin of error was reduced when both length and width of the second metacarpal was used, and change in height was related to the length of the hand, and not to the width of the hand.

Height = 85.36 + (9.04x length of second metacarpal) + (18.31x width of second metacarpal) ± 5.14

Height =96.52+(3.91x length of hand) ± 5.42

It was not possible to select the width of second metacarpal as the dependent variable in the correlation for males in our study, because it did not have a high correlation. In addition, the formula established using only the length of the second metacarpal has the highest standard deviation (±5.965). Together with this, it has a value similar to that of Özaslan's study. However, the formula obtained using body weight, body mass index, length of hand, and width of hand allows calculation of height rather accurately, with a standard error margin of ±0,870.

In the study of Tuğcu and colleagues [40] on 302 individuals living in Turkey, height establishing was performed using upper extremities, and a standard error margin of 56.17 was reported for the estimation from the length of hand in males, and 60.63 for females, while the same was 65.80 in males and 62.03 for females in estimations from the width of hand. Body mass index and body weight parameters were not taken into consideration in these last two studies. Margin of standard error of the formula reduces when these parameters are taken into consideration.

We believe that the formulas we have established in this study will contribute to the Turkish population, forensic anthropology science, to studies that more than one method is desired, and to height estimations using mathematical methods when estimation of height from highly disintegrated body or skeletal parts is required.

References

1. Wurm H. Zur Geschichte der Körperhöhenschatzung nach Skelettfunden Die vorgeschlagenen Ansaetze zur Körperhöhenschatzung nach Skelettfunden seir der Mitte des 20. Jahrhundrets. Gegenbaurs Morph. Jahrb. 1985;3:383-432.
2. Trotter M, Gleser GC. Estimation of stature from long bones of American Whites and Negroes. Am J Phys Anthropol 1952;10(4):463-514.
3. Trotter M, Gleser GC. A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. Am J Phys Anthropol 1958;16(1):79-123.
4. Telkka A, Palkama A, Virtama P. Estimation of stature from radiographs of long bones in children. Ann Med Exp Biol Fenn 1962;40:91-6.
5. Telkka A. On the prediction of human stature from the long bones. Acta Anat (Basel) 1950;9(1-2):103-17.
6. Abrahamyan DO, Gazarian A, Braillon PM. Estimation of stature and length of limb segments in children and adolescents from whole-body dual-energy X-ray absorptiometry scans. Pediatr Radiol 2008;38:311-315.
7. Bidmos MA. Estimation of stature using fragmentary femora in indigenous South Africans. Int J Legal Medicine Published online: 28 September 2007.
8. Krishan K. Estimation of stature from footprint and foot outline dimensions in Gujjars of North India. Forensic Sci Int 2008;175(2-3):93-101.
9. Krishan K, Kumar R. Determination of stature from cephalo-facial dimensions in a North Indian population. Leg Med (Tokyo) 2007;9(3):128-33.
10. Giroux CL, Wescott DJ. Stature estimation based on dimensions of the bony pelvis and proximal femur. J Forensic Sci 2008;53(1):65-8.
11. Krishan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. J Forensic Leg Med 2007;14(6):327-32.
12. Özaslan A. El ve 2. Metakarp Ölçümlerinden Vücut Boy Uzunluğunun Hesaplanması. Uzmanlık Tezi. İstanbul Üniversitesi Cerrahpaşa Tıp Fakültesi Adli Tıp Anabilim Dalı. İstanbul. 1996.
13. Bhatnagar DP, Thapar SP, Batish, MK. Identification of Personal Height form the Somatometry of the Hand in Punjabi Males. Forensic Sci Int 1984;24:137-41.
14. Özaslan A, İşcan MY, Özaslan İ, Tuğcu H, Koç S. Yaşayan İnsanda El Ölçümünden Cinsiyet Tespiti. Adli Bilimler Dergisi 2002;(1)1:15-21.
15. Bass W. Human Osteology A laboratory and field manual. 3rd ed. Columbia: Missouri Archaeological Society, 1987.
16. Lundy JK. Estimating Living Stature From Skeletal Remians. J Forensic Med 1987;3(1-4):103-110.
17. Petrovečki V, Mayer D, Šlaus M, Strinovic D, Škavic J. Prediction of stature based on Radiographic Measurements of Cadaver Long Bone's A Study of the Croation Population. J Forensic Sci 2007;52(3):547-552.
18. Pelin C, Duyar İ, Kayahan EM, Zağyapan R, AğÍldere AM, Erar A. Body height estimation based on dimensions of sacral and coccygeal vertebrae. J Forensic Sci 2005;50(2):294-297.
19. Holland TD. Brief Comminication : Estimation of adult stature from the calcaneus and talus. Am J Phys Anthropol 1995;96(3):315-320.
20. İşcan MY. Rice of Forensic Anthropology. Yearbook of physical Anthropology 1998; 31:203-230.
21. Byers S, Akoshima T, Curren B. Determination of adult stature from metatarsal length. Am J Phys Anthropol 1989;79(3) : 275-9.
22. Ashizawa K, Kumakura C, Kusumato A, Narasaki S. Relative foot size and shape to general body size in Japanese, Filipians and Japanese with spesial reference to habitual foot war types. Ann Hum Biology 1997;24:117-29.
23. Compobasso CP, Vella G, Introna FJr. Using scapular measurements in regression formulae for the estimation of stature. Boll Soc İtal Sper 1998;74(7-8):75-82.
24. Tibbets GL. Estimation of suture from the vertebral column in American Blacks. J Forensic Sci 1981;26:715-23.
25. Nagesh K, Kumar GP. Estimation of stature from vertebral column length in South Indians. Legal Medicine 2006;8(5):269-272.
26. Lundy JK. The mathematical versus anatomical methods of suture estimate from long bones. Am J Forensic Med Path 1985;6:73-76.
27. Rösing FW. Körperhöhen rekonstruktion aus Skelettmaßen. In: Knußmann R, ed. Anthropologie: Handbuch der vergleichenden Biologie des menschen. 4. Auflage. Stuttgart: Gustov Fischer, 1988:586-599.
28. Duyar İ, Pelin C. Body height estimation based on tibia length in different stature groups. Am J Phys Anthropol 2003;122:23-27.
29. Pelin C, Duyar İ. Estimating stature from tibia length: A comparison of methods. J Forensic Sci 2003;48:708-712.
30. Duyar İ, Pelin C, Zağyapan R. Adli antropolojik olgularda boy hesaplanması için yeni bir yöntem. Adli Bilimler Dergisi 2004;3(1):53-59.
31. Saatçioğlu A. Türkiye'de antropolojik bazı karakterlerin sosyo-ekonomik gruplar arasında gösterdiği değişimler üzerinde biyometrik bir inceleme. Antropoloji 1975;7: 165-200.
32. Kimura K. Estimation of adult stature from second metacarpal, J Natl Def Med Coll 1991;16(2):117-20.
33. Krogman WM, ışcan MY. The Human Skeleton in Forensic Medicine. Second Edition, Springfield, Illinois, USA. Charles C Thomas Publisher, 1986.
34. Himes JH, Yarbrough C, Martorel R. Estimation of stature in children from radiographically determined metacarpal length. J Forensic Sci 1977;22:452-456.
35. Kimura K. Estimation of stature from second metacarpal length in Japanese Children. Annals of Human Biology

1992;19(3):267-75.
36. Abdel-Malek AK, Ahmed AM, El-Sharkawi SA, El-Hamid NA. Prediction of stature from hand measurements. Forensic Sci Int 1990;46(3):181-187.
37. Jindal D, Sing M, Kler GS, Chattopadhyay PK. Estimation of Stature Hand Measurements, J Forensic Med Tox 1992;8(1-4):79-83.
38. Meadows L, Jantz RL. Estimation of stature from metacarpal lengths. J Forensic Sci 1992;37(1):147-54.
39. Musgrave JH, Herneja NK. The estimation of adult stature from metacarpal bone length. Am J Phys Anthropol 1978;48(1) :113-9.
40. Tuğcu H, Özaslan A, Koç S, Özaslan İ. Estimation of stature from upper extremity. Military Medicine 2006;171(4):288-291.

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