Estimation of Stature from Upper Extremity

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With the increasing frequency of mass disasters, identification of an isolated upper extremity and determination of the stature of the person it belonged to have created problems for investigation of the identity of some victims. Despite a need for such a study, there is a lack of systematic studies to identify fragmented and dismembered human remains. The purpose of this study was to analyze anthropometric relationships between dimensions of the upper extremity and body height. Analyses were based on a sample of middle class male (n = 202) and female (n = 108) Turks residing in Istanbul, Turkey. Five variables were entered into the analyses. For male subjects, forearm length was selected as the first factor, followed by hand length and finally upper arm length. For female subjects, upper arm length was selected first, followed by forearm length and finally hand length. There were also individually calculated formulae for some of these measurements that provided smaller R^2 values. The study suggested that estimation of a living height could be made possible by using various dimensions of the upper extremity. One must consider differences between populations to apply such functions to other populations.

Introduction

The estimation of stature from various skeletal elements has been an area of critical interest to anthropologists and medical scientists for nearly 100 years.[1] A variety of mathematical techniques have been developed to estimate living stature from skeletal remains. The most widely used technique in many parts of the world is that devised by Trotter and Gleser.[2–5] The earthquake in Turkey in August 1999 and the terrorist attack on the World Trade Center created great challenges to identification efforts. The same is true for all mass disasters (wars, accidents, terror events, and natural disasters), where proper stature estimation is important for identification of the victims.

There have been already some attempts using lower leg length and arm span,[6] foot dimensions,[7–10] and hand measurements[11–17] to estimate body height. Despite the need, there is a lack of systematic studies to identify fragmented and dismembered human remains.

The purpose of this study was to analyze anthropometric relationships between various dimensions of the upper extremity and body height. Analyses were based on a sample of middle class male and female adult Turks with various statistical subroutines, particularly regression analysis.

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Presented at the 3rd European Academy of Forensic Science meeting, September 22–27, 2003, Istanbul, Turkey.
This manuscript was received for review in October 2004. The revised manuscript was accepted for publication in February 2005.

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Methods

A total of 310 adult Turks (202 male and 108 female subjects) were measured. The participants were students, staff members from the Cerrahpaşa Medical Faculty, staff members from the State National Institute of Forensic Medicine, and military personnel who lived in Istanbul. These individuals were considered middle class, with ≥5 years of elementary education. Included in the study were subjects without any pathological or morphological skeletal changes. The subjects were asked to remove their clothing except for underwear and shoes. They were placed in the standard anatomic position, with the head on the Frankfort horizontal plane. All of the measurements were taken from the left side, according to the procedure described by the International Biological Programme (Fig. 1).[18–20] For the convenience of the readers, the dimensions were taken in 1-mm and 100-g units with standard anthropometric instruments, such as sliding and spreading calipers, anthropometer, steel tape, and scale.

Stature is taken from the vertex to the floor, maintaining the anatomic position and Frankfort plane. Total arm length is measured from the inferior border of the acromial process to the tip of the longest finger, with the subject's arm and hand in a fully extended position. Upper arm length is taken from the marked inferior border of the acromion process to the external superior border of the head of the radius. Forearm length is measured from the marked head of the radius to the tip of the lateral styloid. Hand length is taken as the distance between the middle point of the line connecting the styloid processes and the tip of digit III. Hand width is taken as the distance between the distal tips of metacarpals II and V, with the fingers of the left hand touching each other. This measurement, which is not mentioned in the literature, is thought to be more reliable. Wrist width is taken as the distance between the ulnar and radial styloid processes. All measurements were performed with a millimetric sliding caliper.

The data were analyzed with various subroutines in SPSS (SPSS, Chicago, Illinois), and regression formulas were developed for various combinations to reach the best estimate possible. For stepwise regression analysis, entrance and removal of a variable were based on the statistical significance levels of $p < 0.05$ and $p < 0.10$, respectively. Such a statistical approach has been commonly used in research of this nature.[7,21–23]

Results

Table I shows the descriptive statistics according to gender. The mean age of the subjects included in the study was 30.74 years for male subjects and 35.34 years for female subjects. SDs of the total and upper arm lengths for female subjects were larger than those for male subjects. For other measurements, the opposite was true.

Results of the primary stepwise regression analysis are given

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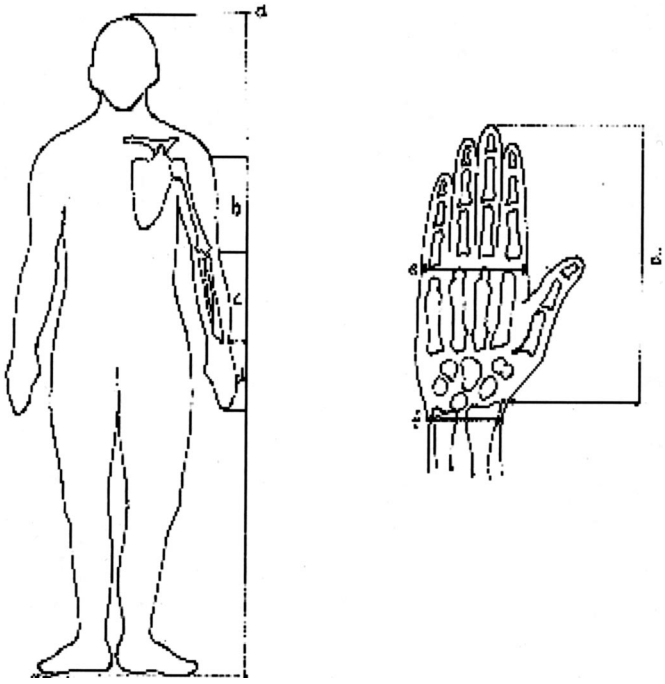

Fig. 1. Anthropometric dimensions used in the study, including stature (*a*), total arm length (*b–d*), upper arm length (*b*), forearm length (*c*), hand length (*d*), hand width (*e*), and wrist width (*f*).

in Table II. Measurements for the analysis consisted of arm and hand dimensions and stature. Five variables were entered into the analysis. Although hand and wrist widths for both female and male subjects were entered into the analysis, they were not used. Forearm length was selected as the first measurement, followed by hand length and finally upper arm length for male subjects. For female subjects, the upper arm length was selected first, followed by forearm length and finally hand length. R indicates the regression coefficient value, and R^2 explains the percentage that a dimension contributes to the variation in the dependent variable (that is, stature). In other words, nearly 38% of variations in stature are inherent in the forearm length for male subjects and 43% of variations in stature are inherent in the upper arm length for female subjects. The addition of the other measurements raises this figure to ~80% in both genders. To consider dismembered body parts, Table III includes dimensions that correlate significantly with stature and can be used alone or in combination with others.

Equations developed with the direct method included total arm length, upper arm length, forearm length, hand length, hand width, and wrist width. The highest R^2 values were associated with total arm length (62%) and forearm length (38%) for male subjects and total arm length (64%) and upper arm length (43%) for female subjects.

Regression formulae generated from a stepwise analysis and five direct analyses to estimate stature for both genders from body parts are given in Table IV. Using the regression formulae of y (stature) = a (constant) + b_1 (regression coefficient for the first variable) x_1 (first variable) + b_2 (regression coefficient for the second variable) x_2 (second variable) + . . . b_n (regression coefficient for the nth variable) x_n (nth variable), one can calculate the height from the dismembered body part. The SE of estimate refers the error that may arise from estimating stature. The use of an equation can be exemplified by considering a lower extremity of a male subject with a total arm length of 727 mm. This dimension is applied to the relevant formula as: stature = 727 mm (total arm length) × 1.63 + 520.956 (constant) = 1,705.97 mm ± 66.08 mm (SE of estimate).

TABLE II

STEPWISE REGRESSION ANALYSIS SHOWING THE SEQUENCE OF ENTRANCE OF VARIABLES INTO THE ANALYSIS AND SE OF ESTIMATE, R, AND R^2

Variable	R	R^2	SE of Estimate
Male			
Forearm length	0.61	0.38	52.51
Hand length	0.71	0.51	46.73
Upper arm length	0.73	0.53	45.75
Female			
Upper arm length	0.66	0.43	48.76
Forearm length	0.73	0.53	44.70
Hand length	0.74	0.55	43.83

Discussion

Estimation of stature is a major forensic anthropological concern used in the identification of unknown and commingled human remains.[24–26] The procedure to estimate body height is to use its components. The accuracy is usually more reliable when the parts are situated along its length, such as the lengths of the femur and tibia more than the humerus and radius in the skeleton.[5] The present study takes this into consideration and uses similar measurements from living people. Obviously, there is a need for such a study.

TABLE I

DESCRIPTIVE STATISTICS OF AGE AND VARIOUS UPPER EXTREMITY DIMENSIONS FOR MALE (N = 202) AND FEMALE (N = 108) SUBJECTS

	Male				Female			
Variables	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Age (years)	30.7	10.36	20	59	35.3	9.13	19	71
Stature (mm)	1,719.3	66.27	1,546	1,975	1,617.5	64.46	1,462	1,848
Total arm length (mm)	736.3	32.12	644	856	689.4	33.30	622	806
Upper arm length (mm)	305.2	18.98	251	383	289.8	19.95	248	342
Forearm length (mm)	244.9	15.19	207	304	230.8	12.64	201	268
Hand length (mm)	192.8	10.44	163	260	180.1	6.76	167	200
Hand width (mm)	82.8	4.91	61	97	76.1	3.97	68	86
Wrist width (mm)	57.3	3.89	48	69	51.4	2.62	45	61

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TABLE III

DIRECT REGRESSION ANALYSIS INCLUDING R, R^2, AND SE OF ESTIMATE

Regression Analysis	Male			Female		
	R	R^2	SE of Estimate	R	R^2	SE of Estimate
Total arm length	0.79	0.62	40.83	0.80	0.64	38.77
Upper arm length	0.45	0.20	59.35	0.66	0.43	48.76
Forearm length	0.61	0.38	52.51	0.51	0.25	55.69
Hand length	0.53	0.29	56.17	0.35	0.12	60.63
Hand width	0.14	0.02	65.80	0.29	0.08	62.03
Wrist width	0.18	0.03	65.30	0.14	0.02	64.14

TABLE IV

REGRESSION COEFFICIENTS AND SE OF ESTIMATE USED TO CALCULATE STATURE

Variables	Regression Equations				
	Stepwise	Total Arm Length	Upper Arm Length	Forearm Length	Hand Length
Male					
Total arm length *b*		1.63			
Upper arm length *b*	0.595		1.569		
Forearm length *b*	1.853			2.673	
Hand length *b*	2.304				3.389
Constant	639.777	520.956	1,240.51	1,064.65	1,066.06
SE of estimate (mm)	74.29	66.08	67.426	59.847	73.229
Female					
Total arm length *b*		1.551			
Upper arm length *b*	1.615		2.127		
Forearm length *b*	1.660			2.604	
Hand length *b*	1.505				3.356
Constant	495.164	548.553	1,001.14	1,016.55	1,013.02
SE of estimate (mm)	103.576	77.678	68.650	98.437	156.375

Stature could have been estimated relatively simply instead of stripping the soft tissue to expose the bone. Anthropometry has enjoyed popularity over the years as a reliable technique to measure the human body and its components.[25] Almost all human growth studies use this method. The technique requires considerable experience, so that the measurements obtained are comparable to those taken by others. For osteological remains, errors are relatively less, especially in length dimensions, because a long bone is relatively simpler to measure. However, there are numerous difficulties in anthropometric measurements of living subjects arising from determination of the correct landmark on the body.

The population in this study differs from other European and North American populations with which most of the studies are done. This difference may be particularly significant in the proportions of one body segment versus another. Turks are shorter than Europeans, and body proportions may also differ. One must consider differences between populations to apply such functions to other populations.

In our previous study on lower extremities, we found that stature estimations were possible with a 7-cm SE.[27] This study indicated that stature estimation can be made with a SE of <7 cm. Therefore, both studies reveal that stature estimation with a 7-cm SE is possible.

In conclusion, estimation of body height from segments or dismembered parts has important considerations for identification of human remains recovered from mass disasters. It is shown that a single dimension can be used to estimate the stature of an unknown person with great accuracy and a small SE (<7 cm).

Acknowledgments

We are grateful to the participants in this study. Without their cooperation, this study could not have been carried out. We thank Özkan Korkut for drawing Figure 1, Dr. Sadık Toprakoğlu for assessing the statistical findings, Elif Günce for assisting in translation, and Can Medical for their efforts to supply the anthropometric equipment used in the study.

This investigation was supported by the Istanbul University Research Fund (Project 1135/05052000).

References

1. Manouvrier L: Stature estimation from the measurements of the hand and the second metacarpal bone. Rev Ec Anthropol 1892; 2: 227–33.
2. Trotter M, Gleser GC: The effect of aging on stature. Am J Phys Anthropol 1951; 9: 311–24.
3. Trotter M, Gleser GC: Estimation of stature from long bones of American whites and Negroes. Am J Phys Anthropol 1952; 10: 463–514.
4. Trotter M, Gleser GC: A re-evaluation of stature based on measurements taken during life and of long bones after death. Am J Phys Anthropol 1958; 16: 79–123.
5. Fully G: New method of determination of height [in French]. Ann Med Leg Criminol Police Sci Toxicol 1956; 36: 266–73.
6. Han T, Lean M: Lower leg length as an index of stature in adults. Int J Obes Relat Metab Disord 1996; 20: 21–7.
7. Giles E, Vallandigham PH: Height estimation from foot and shoeprint length. J Forensic Sci 1991; 36: 1134–51.

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[1] 8. Gordon CC, Buikstra JE: Linear models for the prediction of stature from foot and boot dimensions. J Forensic Sci 1992; 37: 771–82.
9. Singh T, Phookan M: Stature and footsize in four Thai communities of Assam, India. Anthropol Anz 1993; 51: 349–55.
10. Ashizawa K, Kumakura C, Kusumoto A, Narasaki S: Relative foot size and shape to general body size in Javanese, Filipinas and Japanese with special reference to habitual footwear types. Ann Hum Biol 1997; 24: 117–29.
11. Bhatnagar D, Thapar S, Batish M: Identification of personal height from the somatometry of the hand in Punjabi males. Forensic Sci Int 1984; 24: 137–41.
12. Saxena S: A study of correlations and estimation of stature from hand length, hand breadth and sole length. Anthropol Anz 1984; 42: 271–6.
13. Attallah N, Marshall W: The estimation of stature from anthropometric and photogrammetric measurements of the limbs. Med Sci Law 1986; 26: 53–9.
14. Abdel-Malek AK, Ahmed AM, el-Sharkawi SA, el-Hamid NA: Prediction of stature from hand measurements. Forensic Sci Int 1990; 46: 181–7.
15. Shintaku K, Furuya Y: Estimation of stature based on the proximal phalangeal length of Japanese women's hands [in Japanese]. J UOEH 1990; 12: 215–9.
16. Kimura K: Estimation of age at death from second metacarpals. Z Morphol Anthropol 1992; 79: 169–81.
17. Özaslan A: El ve 2nd metakarp ölçümlerinden vücut boy uzunluğunun hesaplanması Uzmanlık Tezi. Department of Forensic Medicine, Medical Faculty of Cerrahpaşa, Istanbul University, Specialty Thesis, Istanbul, Turkey, 1996.
18. Olivier G: Practical Anthropology. Springfield, IL, CC Thomas, 1969.
19. Weiner JS, Lourie JA: Human Biology: A Guide to Field Methods. Oxford, United Kingdom, Blackwell Scientific Publications, 1969.
20. Ulijaszek SJ, Mascie-Taylor CGN (editors): Anthropometry: The Individual and the Population. Cambridge, United Kingdom, Cambridge University Press, 1994.
21. Trotter M: Estimation of stature from intact limb bones. In: Personal Identification in Mass Disasters, pp 71–84. Edited by Stewart TD. Washington, DC, National Museum of Natural History, 1970.
22. Holland TD: Estimation of adult stature from fragmentary tibias. J Forensic Sci 1992; 37: 1223–9.
23. Sjøvold T: Stature estimation from the skeleton. In: Encyclopedia of Forensic Sciences, pp 276–84. Edited by Siegel J, Saukko P, Knupfer G. London, United Kingdom, Academic Press, 2000.
24. İşcan MY: Anthropometry. In: Encyclopedia of Forensic Sciences, pp 284–90. Edited by Siegel J, Saukko P, Knupfer G. London, United Kingdom, Academic Press, 2000.
25. Krogman WM, İşcan MY: The Human Skeleton in Forensic Medicine. Springfield, IL, CC Thomas, 1986.
26. Gordon CC, Bradtmiller B: Interobserver error in a large scale anthropometric survey. Am J Hum Biol 1992; 4: 253–63.
27. Özaslan A, İşcan MY, Özaslan İ, Tuğcu H, Koç S: Estimation of stature from body parts. Forensic Sci Int 2003; 132: 40–5.



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