Original article

Estimation of stature by anatomical anthropometric parameters in first-year regular undergraduate students at Debre Markos University, North West Ethiopia

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Abstract

Introduction: The stature of an individual is an inherent characteristic and is considered as an important parameter of personal identification. Estimating stature from the measurement of various body parts is of particular interest to forensic scientists, anatomists and medical researchers in order to complete biological profiles after death or when measuring standing height is impossible. However, establishing the identity of an individual from mutilated, decomposed and amputated body fragments is a challenging task in medico-legal cases, and a necessity when measuring standing height is difficult.

Objectives of the study: To assess the relationship between anatomical anthropometric measurements and stature in undergraduate students at Debre Markos University (DMU), Ethiopia.

Materials and Methods: An institutional-based, cross-sectional, prospective study was conducted among first-year undergraduate students at DMU. The sample size was 572 and data were collected from April to June 2018. Height, weight, head circumference, head length, inter-acromial length, humeral length, ulnar length, hand length and breadth, tibial length, and foot length and breadth were measured in both sexes. The data were analyzed using SPSS version 25 statistical software. The level of significance was set at $p<0.05$.

Results: The mean age of study participants was 21.27±1.74 years for males and 20.41±1.58 years for females. The mean height of study participants was 168.36±5.89cm for males and 165.24±4.01cm for females. The correlation coefficients (R) of anatomical anthropometric measurements with height were: head circumference (males R = 0.404, females R = 0.127), head length (males R = 0.422, females R = 0.168), inter-acromial length (males R = 0.530, females R = 0.140), right humeral length (males R = 0.539, females R = 0.163), left humeral length (males R = 0.535, females R = 0.159), right ulnar length (males R = 0.496, females R = 0.147), left ulnar length (males R = 0.498, females R = 0.144), right hand length (males R = 0.276, females R = 0.125), left hand length (males R = 0.243, females R = 0.122), right hand breadth (males R = 0.349, females R = 0.129), left hand breadth (males R = 0.331, females R = 0.124), right tibial length (males R = 0.634, females R = 0.259), left tibial length (males R = 0.632, females R = 0.258), right foot length (males R = 0.579, females R = 0.185), left foot length (males R = 0.581, females R = 0.186), right foot breadth (males R = 0.311), left foot breadth (males R = 0.306). The highest correlation was found in the right tibial length in both males and females.

Conclusions: All anatomical anthropometric parameters were significantly ($p<0.05$) correlated with height in both sexes, except foot breadth in females. Therefore, all anatomical anthropometric parameters, including head circumference, head length, inter-acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth, can estimate stature in both sexes, except foot breadth in females. *Ethiop. J. Health Dev.* 2019; 33(3):188-197]

Key words: Estimation of stature, anthropometry, anatomical anthropometric parameters

Introduction

Anthropometric studies are of crucial interest to anatomists, anthropologists and forensic medicine experts. Height is one of the important parameters in anthropometric studies. Stature is the natural height of a person in an upright position. It represents the distance between the top of the head (vertex) and the bottom of the feet. It is an important identifier of an individual(1).

Except in some pathological cases or because of some ecological factors, human body height has a proportional biological relationship with other parts of the body (2). The height of a person, which itself is the sum of the length of certain bones and appendages of the body, has a very important role both in anthropological research and identification processes used by medico-legal experts (3).

Establishing the identity of an individual from mutilated, decomposed and amputated body fragments is a challenging task in medico-legal cases, in the aftermath of natural disasters such as earthquakes, tsunamis and floods, after events such as terrorist attacks, bomb blasts, car accidents, wars and plane crashes, and after deaths caused by attacks by wild animals (4).

The correlation between anthropometric parameters and evaluation of nutritional status relies on accurate measurements of not only body weight but also height. However, some common disabilities and disease processes make it difficult to accurately measure standing height in many patients (5), such as old people, patients with myopathy and spinal disorders, as well as incomplete and decomposing corpses (6). In such situations, estimating stature is of equal importance along with other parameters, such as age, gender and race (together referred to as the 'Big Four' of forensic anthropology) (7).

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Equations produced for one population do not always give accurate results for another population due to differences in the diet, environment and lifestyle of each population (8).

Identification is necessary in the living, recently dead persons, decomposed bodies and skeletal remains, and is also required in civil and criminal law cases when murderer/robber escaped from a prison: to facilitate criminal investigation (9).

Objectives of the study

General objective: To estimate stature by the use of head circumference, head length, inter acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth in first-year regular undergraduate students at Debre Markos University.

Specific objectives

To investigate the relationship between stature and head circumference, head length, inter acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth; and to develop regression models to predict stature using these anatomical anthropometric parameters as well as to assess gender differences between stature and head circumference, head length, inter acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth.

Materials and methods

An institutional-based, descriptive, cross-sectional, prospective study was conducted on 572 students (286 males and 286 females) in the age group 18 to 26 years studying at Debre Markos University, north west Ethiopia. A multistage sampling method was employed to select participants from colleges, schools and institutions of the University. The data were collected from April 2018 to June 2018, entered in EpiData version 3.1 and analyzed in SPSS version 25 statistical software. The level of significance was set at $p<0.05$.

Methods of data collection: Standing height was measured to the nearest 0.1 centimeters (cm) using a stadiometer, with the subject standing erect on a horizontal resting plane, bare footed, with palms of hands turned inwards and fingers pointing downwards. Measurement was from the sole of the feet to the vertex of the head, as recommended by the International Biological Program (10). Weight was measured with a standard mechanical balance. The following anatomical anthropometric parameters of the study subjects were measured in centimeters.

Head circumference: Just above the supercilliary arch on the anterior aspect, above the auricle on the lateral aspect and at the level of the external occipital protuberance on the posterior aspect (11).

Head length: The distance between the glabella and farthest projecting point in the mid-sagittal plane on the back of the head (occiput) (12).

Inter-acromial length: The distance between two bony landmarks, i.e. acromial process of scapula on each side (13).

Humeral length: The distance between the acromion end of the clavicle and olecranon process (14).

Ulnar length: From the tip of the olecranon process to the distal margin of the head of the ulna (15).

Hand length: From the middle of the distal wrist crease to the distal end of the most projecting point of the hand (16, 17).

Hand breadth: The maximum distance between the radial sides of the 2nd metacarpophalangeal joint to the ulnar side of the 5th metacarpophalangeal joint (18).

Tibial length: The distance between the medial most superficial point on the upper border of the medial condyle of the tibia and tip of the medial malleolus (19).

Foot length: The maximum length between the most prominent posterior point of the heel and the tip of the hallux, and the tip of the second toe if it is larger than the hallux (20).

Foot breadth: A straight distance from the most medially placed point on the head of the first metatarsal and the most laterally placed point on the head of the fifth metatarsal when the foot is fully stretched (20).

Measuring instruments

Stadiometer: For measurement of standing height
Weight scale: For measurement of weight
Non-elastic measuring tape meter: For measurements of head circumference, head length, inter-acromial length, humeral length, ulnar length and tibial length.
Sliding caliper: For measurement of hand length, hand breadth, foot length and foot breadth.

Ethical considerations

Ethical clearance was obtained from the postgraduate research office of the Health Science College, Addis Ababa University. Permission was also obtained from the research directorate office of Debre Markos University. Participants were informed about the nature of the study and verbal consent was taken from each participant.

Results

The mean age of respondents was 21.27±1.74 and 20.41±1.58 for males and females, respectively. For males, height ranged from 155.0cm to 182.0cm, with a mean height of 168.36±5.89cm. In females, height ranged from 153.0cm to 178.8cm, with a mean height of 165.24±4.01cm. The minimum, maximum, mean and standard deviation of all anthropometric measurements are provided in Tables 1 and 2.

Table 1: **Descriptive statistics of height, anatomical anthropometric measurements, weight and body mass index of male participants**

Parameters (cm)	Minimum	Maximum	Mean	Standard deviation (SD)
Stature/Height	155.0	182.0	168.36	5.90
Head circumference	49.0	59.6	54.58	2.97
Head length	28.0	35.5	32.18	1.60
Inter-acromial length	30.5	39.0	35.18	1.51
R humeral length	28.5	39.5	33.09	1.93
L humeral length	28.5	39.5	33.12	1.93
R ulnar length	21.1	33.0	25.74	1.56
L ulnar length	21.2	32.9	25.79	1.56
R hand length	15.1	18.1	17.22	0.47
L hand length	15.1	18.2	17.25	0.47
R hand breadth	6.1	8.8	7.54	0.49
L hand breadth	6.2	8.9	7.57	0.49
R tibial length	28.1	45.0	37.05	3.27
L tibial length	28.2	45.0	37.09	3.26
R foot length	18.5	25.0	22.06	1.61
L foot length	18.5	25.0	22.08	1.60
R foot breadth	7.1	10.1	8.75	0.61
L foot breadth	7.1	10.2	8.79	0.61
Weight	45	75	59.23	6.39
BMI	16.32	27.35	20.86	1.55

R = right, L = left, cm = centimeter

Table 2: **Descriptive statistics of height, anatomical anthropometric measurements, weight and body mass index of female participants**

Parameters (cm)	Minimum	Maximum	Mean	Standard deviation (SD)
Stature/Height	153.0	178.8	165.24	4.01
Head circumference	49.0	59.0	53.34	2.95
Head length	28.3	35.0	31.42	1.56
Inter-acromial length	30.5	37.5	34.45	1.49
R humeral length	27.5	36.5	31.83	1.91
L humeral length	27.8	36.5	31.87	1.92
R ulnar length	21.2	29.1	24.75	1.48
L ulnar length	21.3	29.2	24.79	1.49
R hand length	15.0	18.1	17.03	0.54
L hand length	15.0	18.1	17.02	0.53
R hand breadth	6.0	8.5	7.15	0.58
L hand breadth	6.0	8.7	7.17	0.59
R tibial length	28.1	41.8	34.88	3.37
L tibial length	28.2	41.9	34.91	3.36
R foot length	18.0	24.1	20.97	1.45
L foot length	18.0	24.2	20.99	1.46
R foot breadth	6.5	10.1	8.14	0.78
L foot breadth	6.5	10.3	8.18	0.79
Weight	44	76	54.86	6.16
Body mass index (BMI)	15.51	30.25	20.08	2.07

R = right, L = left, cm = centimeter

The strength of gender difference for each anatomical anthropometric measurement was assessed using an independent (unpaired) sample t-test. It was observed that, overall, the mean value of height and all anatomical anthropometric measurements of male participants were greater than those of females, and that all these differences were statistically significant ($p<0.05$). The presence of bilateral asymmetry between right and left anatomical anthropometric measurements were also assessed for male and female participants by using a paired sample t-test. All bilateral anatomical anthropometric measurements in male and female participants exhibited statistically significant bilateral asymmetry. All anatomical anthropometric measurements of male and female participants revealed a positive and statistically significant correlation with height ($p<0.05$), except foot breadth in females (Table 3).

Table 3: **Correlation of height with anatomical anthropometric measurements, weight and body mass index of male and female participants**

	Male = 286		Female = 286	
	Stature/Height		Stature/Height	
Parameters (cm)	**R**	**p**	**R**	**p**
Head circumference (HC)	.404	.001	.127	.032
Head length (HL)	.422	.001	.168	.004
Inter-acromial length (IAL)	.530	.001	.140	.017
Right humeral length (RHuL)	.539	.001	.163	.006
Left humeral length (LHuL)	.535	.001	.159	.007
Right ulnar length (RUL)	.496	.001	.147	.013
Left ulnar length (LUL)	.498	.001	.144	.015
Right hand length (RHL)	.276	.001	.125	.034
Left hand length (LHL)	.243	.001	.122	.039
Right hand breadth (RHB)	.349	.001	.129	.029
Left hand breadth (LHB)	.331	.001	.124	.037
Right tibial length (RTL)	.634	.001	.259	.001
Left tibial length (LTL)	.632	.001	.258	.001
Right foot length (RFL)	.579	.001	.185	.002
Left foot length (LFL)	.581	.001	.186	.002
Right foot breadth (RFB)	.311	.001	.041	.492
Left foot breadth (LFB)	.306	.001	.035	.554
Weight	.725	.001	.406	.001
Body mass index (BMI)	.113	.056	-.034	.562

R = Pearson's correlation coefficient, p = level of significance (<0.05)

Estimations of stature from each anatomical anthropometric measurement of male and female participants are provided in Tables 9 and 10. The standard error of estimate (SEE) ranged from 4.56 to 5.73cm in all anatomical anthropometric measurements of males and the correlation coefficients (R) ranged from 0.243 to 0.634 (Table 4). In females, the SEE ranged from 3.88 to 4.02cm in all anatomical anthropometric measurements and R-values ranged from 0.035 to 0.259 (Table 5).

Table 4: Estimation of stature from each anatomical anthropometric measurement of male participants

Parameters (cm)	**R**	**R^2**	**Adjusted R^2**	**SEE**	**Regression equations**	**Sig.**
Head circumference	.404	.163	.160	5.40	124.58+0.80 HC	.001
Head length	.422	.178	.175	5.35	118.33+1.55 HL	.001
Inter-acromial length	.530	.281	.278	5.01	95.79+2.06 IAL	.001
R humeral length	.539	.291	.288	4.97	113.77+1.65 RHuL	.001
L humeral length	.535	.287	.284	4.98	114.10+1.64 LHuL	.001
R ulnar length	.496	.246	.244	5.13	120.13+1.87 RUL	.001
L ulnar length	.498	.248	.246	5.12	119.68+1.89 LUL	.001
R hand length	.276	.076	.073	5.67	109.03+3.45 RHL	.001
L hand length	.243	.059	.056	5.73	115.74+3.05 LHL	.001
R hand breadth	.349	.122	.119	5.53	136.71+4.20 RHB	.001
L hand breadth	.331	.110	.106	5.57	138.27+3.98 LHB	.001
R tibial length	.634	.402	.400	4.56	125.93+1.15 RTL	.001
L tibial length	.632	.399	.397	4.57	125.93+1.14 LTL	.001
R foot length	.579	.336	.333	4.81	121.59+2.12 RFL	.001
L foot length	.581	.338	.335	4.80	121.17+2.14 LFL	.001
R foot breadth	.311	.096	.093	5.61	142.12+3.00 RFB	.001
L foot breadth	.306	.093	.090	5.62	142.35+2.96 LFB	.001

R = right, L = left, R = correlation coefficient, R^2 = coefficient of determination, SEE = standard error of estimate, Sig. = significance (<0.05)

Table 5: **Estimation of stature from each anatomical anthropometric measurement of female participants**

Parameters (cm)	R	R^2	Adjusted R^2	SEE	Regression equations	Sig.
Head circumference	.127	.016	.013	3.99	156.02+0.17 HC	.001
Head length	.168	.028	.025	3.96	151.67+0.43 HL	.001
Inter-acromial length	.140	.020	.016	3.98	152.22+0.38 IAL	.001
R humeral length	.163	.027	.023	3.97	154.34+0.34 RHuL	.001
L humeral length	.159	.025	.022	3.97	154.61+0.33 LHuL	.001
R ulnar length	.147	.022	.018	3.98	155.41+0.40 RUL	.001
L ulnar length	.144	.021	.017	3.98	155.60+0.39 LUL	.001
R hand length	.125	.016	.012	3.99	146.39+1.11 RHL	.001
L hand length	.122	.015	.011	3.99	146.75+1.09 LHL	.001
R hand breadth	.129	.017	.013	3.99	158.78+0.90 RHB	.001
L hand breadth	.124	.015	.012	3.99	159.22+0.84 LHB	.001
R tibial length	.259	.067	.064	3.88	154.48+0.31 RTL	.001
L tibial length	.258	.066	.063	3.89	154.49+0.31 LTL	.001
R foot length	.185	.034	.031	3.95	154.52+0.51 RFL	.001
L foot length	.186	.035	.031	3.95	154.46+0.51 LFL	.001
R foot breadth	.041	.002	-.002	4.02	163.53+0.21 RFB	.001
L foot breadth	.035	.001	-.002	4.02	163.78+0.18 LFB	.001

R = right, L = left, R = correlation coefficient, R^2 = coefficient of determination, SEE = standard error of estimate, Sig. = significance (<0.05)

Estimations of stature using a combination of bilateral and different anatomical anthropometric measurements of male and female participants are provided in Tables 11 and 12. The standard error of estimate (SEE) ranged from 5.51 (combination of left hand length (LHL) and left hand breadth (LHB)) to 4.41 (combination of right ulnar length (RUL) and right tibial length (RTL)) in males (Table 6). In females, the standard error of estimate (SEE) ranged from 3.98 (combination of right ulnar length (RUL) and left ulnar length (LUL)) to 3.89 (combination of right tibial length (RTL) and left tibial length (LTL)) (Table 7).

Table 6: **Estimation of stature from combinations of anatomical anthropometric measurements of male participants**

Parameters (cm)	R	R^2	Adjusted R^2	SEE	Durbin Watson test	Regression equations (multiple)	Sig.
HC-HL	.444	.197	.192	5.30	1.62	113.98+0.41 HC+1.00 HL	.001
RHuL-LHuL	.543	.295	.290	4.97	1.67	114.02+6.29 RHuL+-4.639 LHuL	.001
RUL-LUL	.499	.249	.244	5.13	1.46	119.56+-1.33 RUL+3.22 LUL	.001
RHL-RHB	.391	.153	.147	5.45	1.48	101.85+2.33 RHL+3.51 RHB	.001
LHL-LHB	.363	.132	.125	5.51	1.47	108.94+1.95 LHL+3.40 LHB	.001
RTL-LTL	.641	.410	.406	4.54	1.38	126.89+7.70 RTL+-6.58 LTL	.001
RFL-RFB	.596	.355	.350	4.75	1.43	112.93+1.96 RFL+1.41 RFB	.001
LFL-LFB	.595	.354	.349	4.76	1.42	113.23+1.98 LFL+1.30 LFB	.001
RUL-RTL	.666	.444	.440	4.41	1.25	110.98+0.89 RUL+0.93 RTL	.001
LUL-LTL	.665	.442	.438	4.42	1.24	110.76+0.90 LUL+0.92 LTL	.001
RHuL-RHL-RFL	.626	.392	.386	4.62	1.46	84.89+0.82 RHuL+1.54 RHL+1.35 RFL	.001
LHuL-LHL-LFL	.623	.388	.381	4.64	1.45	88.44+0.81 LHuL+1.29 LHL+1.40 LFL	.001

R = correlation coefficient, R^2 = coefficient of determination, SEE = standard error of estimate, Sig.= significance at p<0.05, HC = head circumference, HL = head length, RHuL = right humeral length, LHuL = left humeral length, RUL = right ulnar length, LUL = left ulnar length, RHL = right hand length, LHL = left hand length, RHB = right hand breadth, LHB = left hand breadth, RTL = right tibial length, LTL = left tibial length, RFL = right foot length, LFL = left foot length, RFB = right foot breadth, LFB = left foot breadth

Table 7: **Estimation of stature from combinations of anatomical anthropometric measurements of female participants**

Parameters (cm)	R	R^2	Adjusted R^2	SEE	Durbin Watson test	Regression equations (multiple)	Sig.
HC-HL	.170	.029	.022	3.97	1.56	151.07+0.04 HC+0.38 HL	.001
RHuL-LHuL	.194	.038	.031	3.95	1.65	155.11+5.47 RHuL+-5.15 LHuL	.001
RUL-LUL	.154	.024	.017	3.98	1.56	155.37+2.90 RUL+-2.50 LUL	.001
RHL-RHB	.161	.026	.019	3.98	1.58	145.07+0.88 RHL+0.73 RHB	.001
LHL-LHB	.154	.024	.017	3.98	1.58	145.92+0.86 LHL+0.67 LHB	.001
RTL-LTL	.263	.069	.062	3.89	1.52	154.76+2.69 RTL+-2.39 LTL	.001
RFL-RFB	.186	.034	.028	3.96	1.55	154.92+0.53 RFL+-0.08 RFB	.001
LFL-LFB	.187	.035	.028	3.96	1.55	155.02+0.53 LFL+-0.12 LFB	.001
RUL-RTL	.259	.067	.060	3.89	1.53	154.13+0.02 RUL+0.30 RTL	.001
LUL-LTL	.258	.066	.060	3.89	1.53	154.22+0.02 LUL+0.30 LTL	.001
RHuL-RHL-RFL	.205	.042	.032	3.95	1.52	143.90+0.17 RHuL+0.55 RHL +0.32 RFL	.001
LHuL-LHL-LFL	.203	.041	.031	3.95	1.52	144.84+0.15 LHuL+0.50 LHL +0.34 LFL	.001

R = correlation coefficient, R^2 = coefficient of determination, SEE = standard error of estimate, Sig.= significance at $p<0.05$, HC = head circumference, HL = head length, RHuL = right humeral length, LHuL = left humeral length, RUL = right ulnar length, LUL = left ulnar length, RHL = right hand length, LHL = left hand length, RHB = right hand breadth, LHB = left hand breadth, RTL = right tibial length, LTL = left tibial length, RFL = right foot length, LFL = left foot length, RFB = right foot breadth, LFB = left foot breadth

Dependent (paired) t-tests for comparison of estimated statures and actual statures for each anatomical anthropometric parameter in male and female participants are provided in Tables 8 and 9. For all anatomical anthropometric measurements, there were statistically insignificant differences ($p>0.05$) between the mean values of estimated statures and actual statures in male participants (Table 8). It was also observed that there were statistically insignificant differences ($p>0.05$) between mean values of estimated statures and actual statures in female participants (Table9).

Table 8: **Paired sample t-test to see the existence of mean difference between actual and estimated stature of male participants**

Parameters (cm)	Actual mean Ht±SD	Estimated mean Ht±SD	MD	SED	95% CI		T	Sig.
					Lower	Upper		
Head circumference	168.36±5.89	168.355±2.38	.004	.318	-.623	.632	.014	.988
Head length	168.36±5.89	168.368±2.48	-.009	.316	-.631	.613	-.029	.977
Inter-acromial length	168.36±5.89	168.366±3.12	-.006	.295	-.588	.575	-.023	.982
R humeral length	168.36±5.89	168.367±3.17	-.007	.293	-.585	.570	-.025	.980
L humeral length	168.36±5.89	168.353±3.15	.006	.294	-.573	.586	.022	.982
R ulnar length	168.36±5.89	168.361±2.92	-.002	.302	-.597	.593	-.007	.995
L ulnar length	168.36±5.89	168.347±2.93	.012	.302	-.582	.606	.040	.968
R hand length	168.36±5.89	168.353±1.62	.006	.335	-.652	.666	.020	.984
L hand length	168.36±5.89	168.360±1.43	-.001	.338	-.665	.665	-.001	1.00
R hand breadth	168.36±5.89	168.358±2.05	.001	.326	-.642	.644	.003	.998
L hand breadth	168.36±5.89	168.361±1.95	-.002	.328	-.649	.645	-.006	.995
R tibial length	168.36±5.89	168.346±3.73	.012	.269	-.5174	.543	.048	.962
L tibial length	168.36±5.89	168.355±3.72	.004	.270	-.5271	.536	.017	.986
R foot length	168.36±5.89	168.357±3.41	.002	.284	-.556	.561	.009	.993
L foot length	168.36±5.89	168.359±3.42	-.001	.283	-.558	.558	.000	1.00
R foot breadth	168.36±5.89	168.362±1.83	-.003	.331	-.655	.649	-.009	.993
L foot breadth	168.36±5.89	168.363±1.80	-.003	.331	-.657	.649	-.012	.990

Cm = centimeter, Ht = height, SD = standard deviation, MD = mean difference, SED = standard error of mean difference, CI = confidence interval, T = t- statistics, Sig. = level of significance

Table 9: **Paired sample t-test to see the existence of mean difference between actual and estimated statures in female participants**

Parameters (cm)	Actual mean Ht±SD	Estimated mean Ht±SD	MD	SEE	95% CI		T	Sig.
					Lower	Upper		
Head circumference	165.24±4.01	165.256±0.51	-.017	.235	-.481	.445	-.075	.940
Head length	165.24±4.01	165.241±0.67	-.002	.233	-.462	.458	-.010	.992
Inter-acromial length	165.24±4.01	165.241±0.56	-.002	.235	-.465	.460	-.011	.991
R humeral length	165.24±4.01	165.227±0.65	.011	.234	-.449	.472	.050	.960
L humeral length	165.24±4.01	165.252±0.63	-.013	.234	-.474	.448	-.056	.955
R ulnar length	165.24±4.01	165.233±0.58	.005	.234	-.456	.467	.023	.981
L ulnar length	165.24±4.01	165.245±0.57	-.006	.234	-.468	.455	-.027	.978
R hand length	165.24±4.01	165.234±0.50	.003	.235	-.459	.467	.017	.987
L hand length	165.24±4.01	165.246±0.49	-.008	.235	-.471	.455	-.034	.973
R hand breadth	165.24±4.01	165.240±0.51	-.001	.235	-.464	.461	-.007	.995
L hand breadth	165.24±4.01	165.238±0.49	.0004	.235	-.463	.464	.002	.999
R tibial length	165.24±4.01	165.221±1.03	.017	.229	-.434	.468	.075	.940
L tibial length	165.24±4.01	165.241±1.03	-.002	.229	-.454	.448	-.012	.990
R foot length	165.24±4.01	165.238±0.74	.0007	.233	-.458	.459	.003	.997
L foot length	165.24±4.01	165.229±0.74	.009	.233	-.449	.468	.040	.968

Cm = centimeter, Ht = height, SD = standard deviation, MD = mean difference, SED = standard error of mean difference, CI = confidence interval, T = t- statistics, Sig. = level of significance

Discussion

The present study was designed to estimate stature by way of anatomical anthropometric measurements, including head circumference, head length, inter-acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth in 572 students (286 males and 286 females) at Debre Markos University. The age range of the students was 18 to 26 years.

In the study, head circumference was significantly correlated with height in males (R = 0.404, p<0.05) and in females (R = 0.127, p<0.05). This is in line with a study conducted in Nepal of 440 students (258 males and 182 females) in the age group 17 to 25 years (11). This study revealed that head circumference was significantly correlated with height in males (R = 0.443, p<0.01) as well as in females (R = 0.302, p<0.01). However, in the present study, head circumference was weakly correlated with height in females. This difference in strength of association may be due to differences in measurement error, measurement techniques and sample size in the two studies.

In the present study, head length showed better and significant correlation (p<0.05) in both sexes (males R = 0.422, females R = 0.168) with height than head circumference (males R = 0.404, females R = 0.127). This finding contrasts with a study conducted in Nigeria of 500 individuals (261 males and 239 females) in the age group 18 to 30 years (7), in which head circumference had a better and significant correlation (p<0.05) in both sexes (males R = 0.253, females R = 0.203) with height than head length (males R = 0.159, females R = 0.186). This lack of agreement may be due to inherent population variations attributed to genetics and environmental factors in the two studies (21).

In the present study, bi-acromial length was significantly correlated with height in males (R = 0.53, R2= 0.281) and in females (R = 0.14, R2 = 0.20) (p<0.05). This is in line with a study carried out in Turkey of 337 volunteers (216 males and 121 females) in the age group 20 to 52 years (22). In this study, it was reported that bi-acromial length was significantly correlated with height in males (R = 0.42, R2 = 0.176) and in females (R = 0.26, R2 = 0.067) (p<0.01). In both studies, bi-acromial length was a relatively better predictor of stature in males than females. In the present study, a 53% variation of height in males is attributed to bi-acromial length. However, in the study in Turkey, a 17.6% variation of height in males accounted to bi-acromial length. This difference in variation of height due to inter-acromial length may be explained by differences in age group and sample size in the two study populations.

In the present study, humeral length (bilateral) was strongly correlated with height in males (p<0.05). The correlation coefficient (R) was 0.539 and 0.535 for right and left humeral lengths, respectively. In females, the correlation coefficient was 0.163 for right humeral length and 0.159 for left humeral length. This is in line with a study conducted in Iran of 100 students (50 males and 50 females) in the age group 19 to 21 years (14). This study also showed that upper arm length was strongly correlated with height in males (R = 0.631, p<0.01). However, in this study, upper arm length was not significantly correlated with height in females (R = 0.231, p = 0.102). This finding contrasts with the

current study in the case of females. This may be due to differences in sample size and age group, or may be due to variations in genetics and environmental factors in the two study populations.

In the present study, the correlation between height and ulnar length (bilateral) in males and females was statistically significant ($p<0.05$). The correlation coefficient (R) of right ulnar length was 0.496 for males and 0.147 for females. The correlation coefficient of left ulnar length was 0.498 for males and 0.144 for females. This is in agreement with a study conducted in Andhra Pradesh, India, of 100 students (50 males and 50 females) in the age group 21 to 24 years (23). This study revealed that the correlation coefficient of ulnar length with height in males was 0.93 for both right and left ulnar lengths. In females, the correlation coefficient was also 0.63 for right ulnar length and 0.61 for left ulnar length. In both studies, ulnar length was more strongly correlated with height in males than females.

In the current study, hand breadth had a better correlation (R = 0.349, R = 0.129) in predicting stature than hand length (R = 0.276, R = 0.125) in both males and females, respectively. This finding contrasts with the findings of a study conducted in India of 268 adults (158 males and 110 females) in the age group 20 to 39 years (24). This study revealed that hand length had better correlation (R = 0.56, R = 0.51) in predicting stature than hand breadth (R = 0.31, R = 0.36) in both males and females, respectively. This disagreement may be due to differences in age group, sample size, measuring instruments, or due to genetics and environmental factors.

In the present study, tibial length was strongly correlated with height in both males and females ($p<0.05$). The correlation coefficient (R) between height and tibial length in males was 0.634 and 0.632 for right and left tibial lengths, respectively. The correlation coefficient (R) between height and tibial length in females was 0.259 and 0.258 for right and left tibial lengths, respectively. This finding is supported by a study of 540 students (270 males and 270 females) in the age group 18 to 21 years in Madhya Pradesh, India (25). In this study, it was reported that the correlation coefficient (R) between height and tibial lengths in males was 0.417 and 0.442 for right and left tibial lengths, respectively; in females, the correlation coefficient was 0.570 and 0.604 for right and left tibial lengths, respectively.

In the present study, foot length was significantly correlated with height in both males and females ($p<0.05$). The correlation coefficient (R) of height with foot length was R = 0.579, R = 0.581 and R = 0.185, R = 0.186 in males and females for right and left foot lengths, respectively. This finding is supported by a study conducted in Nagpur, India, with 640 students (343 males and 297 females) in the age group 18 to 23 years (20). This study revealed that there was strong correlation between height and foot length, as well as foot breadth, in both sexes. The correlation coefficient of foot length with height in males was 0.97 and 0.96 for right and left foot lengths respectively; in females, the correlation coefficient was also 0.986 and 0.984 for right and left foot lengths, respectively. However, in the present study, foot breadth was insignificantly correlated with height in females ($p>0.05$) and less likely predict height of females. The differences between the two studies may be due to differences in measuring instruments and measuring error, or be due to genetic and environmental factors, such as nutrition and climate, in the two study populations.

In the present study, multiple linear regression models were relatively better predictors of stature than simple linear regression models in both males and females. This finding agrees with a study conducted with 1,000 students (536 males and 464 females) in the age group 19 to 22 years in Maharashtra, India, which concluded that multiple linear regression equations were a better predictor of stature than simple linear regression equations (26).

In the present study, gender differences in the mean values of height, head circumference, head length, inter-acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth were significantly greater in males than those of females ($p<0.05$). This finding is similar to findings of studies conducted in Maharashtra (India), Nigeria and western India (26-28).

Conclusions

Almost all anatomical anthropometric parameters – head circumference, head length, inter-acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth – were significantly correlated with height in both sexes ($p<0.05$). However, foot breadth was insignificantly correlated with height only in females ($p>0.05$).

Of all the anatomical anthropometric parameters studied, foot length, humeral length and tibial length were strongly correlated with height in males. Similarly, among all anatomical anthropometric parameters studied, only foot length and tibial length were strongly correlated with height in females. However, hand length revealed the lowest correlation with height in both males and females.

The mean height of males was higher than that of females and this difference was statistically significant ($p<0.05$). The mean of all anatomical anthropometric parameters was higher in males than females, and this gender differences in mean values of all anatomical anthropometric parameters were statistically significant ($p<0.05$).

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