ADDIS ABABA UNIVERSITY

COLLEGE OF HEALTH SCIENCES

SCHOOL OF MEDICINE

DEPARTMENT OF ANATOMY

ESTIMATION OF STATURE BY ANATOMICAL ANTHROPOMETRIC PARAMETERS IN FIRST YEAR REGULAR UNDERGRADUATE STUDENTS OF DEBRE MARKOS UNIVERSITY, NORTH WEST ETHIOPIA

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DECLARATION

I solemnly declare that this thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate. I have followed all ethical principles of scholars in the preparation of the proposal, data collection, data analysis and completion of this thesis. All scholarly matter that is included in this thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this thesis. Every effort has been made to avoid plagiarism in the preparation of this thesis.

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By my signature below, I declare and affirm that this thesis is my own work.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAU ……………………………….Addis Ababa University

DMU……….. …………………….. Debre Markos University

HC…………………………………..Head circumference

HL………………………………….. Head length

IAL………………………………….Inter-acromial length

LFB …………………………….......Left foot breadth

LFL ………………………………….Left foot length

LHB ………………………………….Left hand breadth

LHL ………………………………….Left hand length

LHuL ……………………………….. Left humeral length

LTL...………………………………….Left tibial length

LUL…………………………………...Left ulnar length

PSU …………………………………..Primary sampling unit

RFB……………………………………Right foot breadth

RFL ……………………………………Right foot length

RHB …………………………………... Right hand breadth

RHL……………………………………Right hand length

RHuL …………………………………...Right humeral length

RTL……………………………………..Right tibial length

RUL …………………………………… Right ulnar length

SNN……………………………………...Southern nation and nationalities

SSU ……………………………………..…Secondary sampling unit

TSU…………………………………......Tertiary sampling unit

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ABSTRACT

Introduction: Stature of an individual is an inherent character and is considered as one of the important parameter of personal identification. Estimation of stature from measurement of various body parts is a particular interest to Forensic scientists, Anatomists and Medical researchers to complete biological profile after death or when measuring standing height is impossible. However, establishing identity of an individual from mutilated, decomposed and amputated body fragments has become a challenging task in medico-legal cases and a necessity when measuring standing height is difficult.

Objective of the study: To estimate stature by the use of anatomical anthropometric parameters in first year regular undergraduate students of Debremarkos University (DMU).

Materials and Methods: Institution based cross sectional prospective study was conducted in first year regular undergraduate students of DMU. The sample size was 572 and data was 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, foot length and breadth were measured in both sexes. The data was analyzed through SPSS version 25. 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 also 168.36 ± 5.89 cm for males and 165.24 ± 4.01 cm 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 depicted in right tibial length in both males and females.

Conclusion: 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.

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

1. INTRODUCTION

1.1. Back ground

Anthropometric studies are main interests for Anatomists, Anthropologists and Forensic medicine experts. Height is one of the important parameter in anthropometric study of humans. Stature is natural heights 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 physical identity (1).

Stature is an anatomical complex that includes dimensions of legs, pelvis, vertebral column and skull; and contribution of each of these to the total varies in different individuals and also in different populations (2). The legs should be kept parallel to each other with both feet joined together and the great toe should face forward. The person should stand barefooted and should maintain anatomical position of the body with head adjusted in Frankfurt plane (1, 3). Stature estimation is an indispensable part of the identification process of human skeletal remains or body parts (4).

Except in some pathological cases or under some ecological factors, human body height has proportional biological relationship with other parts of the body (2). Height of a person, which itself is a sum of the length of certain bones and appendages of the body, represent certain relationship with form of proportions to the total stature. It takes a very important role both in anthropological research and identification process necessitated by medico legal experts (5).

Stature measurement is also essential for comparison of different populations. It represents the length of the body from the head to foot when standing erect. Usually it is done by measuring length of long bones. It can also be done by measuring short bones of hands and feet (6).

Body segments exhibit consistent ratio with stature, age, gender and race. Prediction is an important subject in almost all life sciences (7, 8). There is definitive biological correlation of stature with all body parts such as extremities, head, trunk, vertebral column, etc. There are variations in length of limb bones relative to stature and according to race, sex, age, size of body, climate, heredity and nutrition (9).

There exists a strong relationship between stature and dimensions of different body parts, particularly bone lengths, which forms basis for stature estimation. The height of the new generation is increasing with improved socioeconomic condition of the world (1). After the age of 21 – 25 years, dimensions of the skeleton remain unchanged and the ratio in size of different parts to one another is also considerably variable in different individuals (10). Stature provides insight into various features of a population including nutrition, health, genetics, geographical location, environment and climatic condition (11).

Estimation of height from measurement of various body parts is a particular interest to many Anthropologists, Anatomists and Forensic scientists for its importance in medico-legal cases. Height is fundamental for assessing growth, nutrition, calculating body surface area and predicting pulmonary function during childhood (12).

Researchers and Forensic practitioners have conducted numerous scientific studies geared at the estimation of stature. These studies have thus yielded two different estimation methods, anatomical and mathematical methods. The first of these is based on addition of skeletal elements from skull to calcaneus. The second method estimates living stature by considering the length of long bones, generally determined with the help of regression equations. The anatomical method has some limitations when it comes to those cadavers which have lost their physical integrity or have decayed. This is being the case; experts tend to estimate stature using mathematical method more. There are various techniques for applying mathematical method. While some researchers simply consider ratio of skeletal elements to living stature, others prefer estimating stature via regression techniques. Due to its practically, it has been become the most common technique for estimating living stature (13).

Though anatomical method is more accurate but often complete skeletal remains are unavailable from a crime scene and therefore Forensic anthropologists as well as Medico legal experts reconstruct stature from relatively less precise mathematical method which is workable even if only a single long bone is available (14).

1.2. Statement of the Problem

Establishing the identity of an individual from mutilated, decomposed and amputated body fragments has become a challenging task in medico-legal cases and a necessity in recent times due to natural disasters like earthquakes, tsunamis, floods and man-made disasters like terrorist attacks, bomb blasts, car accidents, wars, plane crashes, etc. Victims are also attacked by wild animals in deep forests which makes difficult to identify the deceased (9).

On the other hand, correlation of height from pharmacokinetic parameters and evaluation of nutritional status rely on accurate measurements of not only body weight but also height. However a number of common disabilities and disease processes make it difficult to accurately measure standing height in many patients (15). Such as old people, myopathy, spinal disorder patients and also incomplete and decomposing corps (16). In such situations as stated above, estimation of stature becomes equally important along with other parameters which are age, gender and race (together referred to as the 'Big Four' of forensic anthropology) (17).

Each race requires its own formula for stature estimation because racial and ethnic variations exist in population of different geographical regions. The climate and dietary habits of the people of different regions are variable (9). Bone length and height of an individual are influenced by numerous factors such as age, gender, race, climate, nutrition and genetic factors (4).

Equations produced for one population do not always give accurate results for another population due to differences in diet, environment and lifestyle of each population (18). Identification becomes necessary in the living, recently dead persons, decomposed bodies, skeletal remains and is required in civil and criminal cases (19).

The earthquake in Turkey in August 1999 and terrorist attack on world Trade Centre in September 2001 create great challenges to the identification effort (19). Recently similar identification problems were encountered in our country during garbage dump land slide at Koshe in Addis Ababa.

1.3. Significance of the Study

The findings of this study will help Forensic scientists, Anatomists and Medical researchers to estimate stature from dismembered and mutilated body parts in forensic examinations to complete biological profile after death for medico legal issues.

In addition, the findings of this study will be used as alternative measurement tool in a number of common disabilities and disease processes when it is difficult to accurately measure standing height in many patients.

Moreover, the findings of the study will serve an investigator in field epidemiology when height caliber (Stadiometer) is not available or difficult to move from place to place. The findings of this study will also be used as a reference data for further detailed studies.

2. LITERATURE REVIEW

2.1. Factors affecting stature

Height variation is known to be determined by both genetic and environmental factors. Genetics is more influential during late adolescence (20, 21). The proportion of height variation explained by shared environmental factors was greatest in early childhood, but these effects remained present until early adulthood. Accordingly, the relative genetic contribution increased with age and was greatest in adolescence (up to 0.83 in boys and 0.76 in girls). Comparing to geographic-cultural regions (Europe, North-America, Australia and East-Asia), genetic variance was greatest in North-America and Australia, and lowest in East-Asia. However the relative proportion of genetic variation was roughly similar across these regions (21). Physical environment is known to be a major influence of long ranged adaptation difference in human body size and proportion (22). People, particularly of lower socioeconomic status, that live at high altitudes, or have experienced poor nutrition and health, was not reach their true genetic potential (23). Malnutrition results in failure to grow, involving both weight and height (24). Growth retardation is proportional to the degree of hypoxia, and hypoxia exists along an altitude gradient. For example at 4,500 meters, the partial pressure of oxygen is decreased up to 40 percent (25). People who reside in warm environment have relatively longer limb and narrower body than those from cold environment (22).

2.2. Height difference in males and females

The origin of height difference between males and females is most commonly hypothesized to result from hormonal environment and sex chromosome composition. Sex steroids such as estradiol and testosterone are highly relevant for growth in closure of growth plates in the long bones. They also affect the secretion of other growth-related hormones such as growth hormone and insulin-like growth factors. Therefore it is reasonable to hypothesize that differential sex steroid patterns may produce at least some part of sex difference in height (26). The influences of sex chromosomes are suggested by aneuploidies of sex chromosomes such as Turner's, Klinefelter's and XYY syndromes but mechanisms of action are not fully understood. Females with Turner's syndrome lack one copy of X-chromosome (45, X0) and are characterized by short stature and ovarian failure while males with Klinefelter's syndrome carry an extra copy of X-chromosome (47, XXY) and manifest mild mental retardation and slightly taller on average compared to males with normal karyotype. Height manifestations in these aneuploidies suggest that sex chromosomes may influence height via dosage effect of pseudo autosomal and Y-specific growth genes although specific genes have yet to be identified (27).

2.3. Effect of aging on height

It is generally accepted that height declines with age. Height will begin to decrease in mid 40s in United States populations. This minimal decrease begins for males at about 1 mm/year and about 1.25 mm/year in females (26). Galloway (1988) found that height reduces on average by 0 .16 cm per year after age 45. She suggested that 0.16 cm times (age minus 45) should be incorporated into stature estimation equations when analyzing older individuals above 45 years old. Trotter (1952) states that height decreases from year thirty by 0.06 cm per year and recommends 0.06 times (age minus thirty) should be incorporated into stature estimation equations when analyzing older individuals above 30 years old (28). It is known that intervertebral disks tend to compress due to appearance of micro fractures, stiffen and become more fibrous with increasing age, causing total vertebral length to decrease resulting in an overall loss in height (29).

2.4. Correlation of head circumference and head length with stature

A study was conducted on 500 subjects (261 males and 239 females) in the age group 18 to 30 years in Nigeria. This study revealed significant correlation of head length and head circumference with stature in males and females ($p<0.05$). Males had significantly greater mean value of head length ($P<0.001$), head circumference ($P<0.001$) and stature ($P<0.001$) than that of females. The correlation between stature and head length in males was ($R = 0.159$, $P<0.05$) and in females was ($R = 0.186$, $P<0.01$). The correlation between stature and head circumference in males was ($R = 0.253$, $P<0.001$) and in females was ($R = 0.203$, $P<0.01$) (17).

Another study was conducted on 300 medical students (150 males and 150 females) in the age group 18 to 25 years in Maharashtra showed that mean height of males was significantly higher (169.10 ± 6.15 cm) than females (157.36 ± 4.63 cm). The mean head length (HL) and head circumference (HC) were higher for males than that of females, and this gender difference was found to be statistically significant ($p<0.05$). The correlation coefficient of HC was 0.733 and

0.654 for males and females respectively. The correlation coefficient of HL was 0.745 and 0.677 for males and females respectively. Both head length and head circumference had significant correlation with stature ($p < 0.001$) (30).

A study was also carried out on 470 medical students (males 260 and females 210) in the age group 18 to 24 years in India to determine stature using head length and head breadth. The correlation coefficients of head length with height were 0.279 and 0.206 for males and females respectively. Hence head length had relatively greater correlation coefficient in males than females. Head length was relatively a better criteria for males than females for stature estimation (9).

Another study was also done on 208 medical students (148 males and 61 females) in the age group 17 to 26 years in CSM Medical University UP revealed that head length can be used for predicting heights with fair degree of accuracy in males. The correlation coefficient of head length for males was 0.74. However in females, correlation coefficient of head length was 0.0069 and little importance for predicting height in females (7).

A similar study was conducted in Kathmandu University, Nepal consisted of 440 students (258 males and 182 females) in the age group 17 to 25 years to estimate stature from head circumference. This study showed significant correlation between height and head circumference ($r = 0.443$, $p < 0.01$ for males and $r = 0.302$, $p<0.01$ for females) (31).

A study was carried out in Kosovo Albanian population to predict body height by using head circumference, head height and face height. This study concluded that head height, head circumference and face height significantly ($p<0.000$) predicts 26.2% of total variance of body height. The predicted body height had high significant correlation with true living body height and no significant difference was observed between predicted height and living body height (8).

A study was conducted on 150 students (75 males and 75 females) in the age group 20 to 28 years in Indo-Mauritian population to estimate stature on the basis of craniofacial dimensions. This study remarked that stature and craniofacial measurements of males were significantly higher than that of females except for nasal height where no significant difference was observed ($p >0.05$). However estimation of stature is not reliable with the help of cephalo-facial dimensions (32).

2.5. Correlation of inter-acromial length with stature

A study has been conducted to establish relationship between heights of different persons and their inter-acromial lengths in Western Uttar Pradesh region of India. In this study, p- value was 0.178 for females and 1.408 for males. In case of females, the p- value indicates that approximately statistically significant but not accurate. In the case of males, the p- value was more than 0.05, it was 1.408. This indicates that correlation was much more greater than threshold value so that the result was statistically insignificant in case of males (33).

Another study was conducted on 100 medical students of age between 22 to 29 years to estimate stature from inter acromial length in Karamsad tertiary care institute, India. The findings of the study showed that correlation coefficient between stature and inter-acromial length was 0.27 for females and 0.48 for males. However it was concluded that inter-acromial length had limited forensic value and relatively low reliability in this study (34).

An observational study was conducted on 300 subjects (150 males and 150 females), belonging to the age group 22 to 44 years, to estimate stature from inter-acromial length in department of Forensic Medicine, Gujarat , India. The findings of this study showed a positive correlation between stature and inter-acromial length in males and females combined ($p < 0.001$) which was highly significant. In this study, the standard error was ± 6 cm for males and ± 5 cm for females. The correlation coefficient (r) was 0.59 for males and females combined. However in case of males only, $r = 0.31$ and in case of females only, $r = 0.23$. This showed low degree of positive correlation in case of males and females measured separately (35).

Another study was done on 337 adults (216 males and 121 females) living in Turkey to estimate stature from bi-acromial length. The findings of this study showed that there was significant correlation (r) between stature and bi-acromial length. The correlation coefficient was $r = 0.42$ for males and $r = 0.26$ for females. Gender differences were found to be highly significant for bi-acromial length measurements (36).

2.6. Correlation of humeral length with stature

A study was conducted on 100 students (50 males and 50 females) in the age group 19 to 21 years in Tehran University of Medical Sciences to estimate stature from percutaneous length of humerus. The findings of this study showed that mean age of males was 20±1.2 years and females was 21±1.81 years. A significant difference was observed in heights of male and females (P = 0.0001). There was also a significant difference in upper arm lengths of males and females (P = 0.0001). In addition, there was a correlation between height and upper arm length of males and females combined (r = 0.716, P = 0.0001). According to findings of this study, upper arm length (UAL) can be a reliable body dimension for predicting stature in Iranian medical students (37).

Another study conducted in Korea to develop regression equations for stature estimation using upper limb bones. A total of 105 samples (55 men and 50 women) obtained from cadavers were used for developing equations. The findings of this study showed that coefficient of determination (R^2) of variables was slightly higher in men than that of women. The maximum length of humerus was used to estimate stature when unidentified human bones are found at excavation sites ($R^2 = 0.949$) (38).

A comparative study was carried out in India to examine the relationship between height and arm length among 160 adults (20 to 50 years) of which 80 were Muslim and 80 were Hindu of Gujarat. The findings of this study showed that Hindu revealed significantly higher correlation coefficient value (r) than Muslim of Gujarat. There was positive significance correlation for males and had higher mean values than that of females. Simple linear regression showed more reliable results compared to multiple linear regression analysis (39).

2.7. Correlation of ulnar length with stature

A study was conducted on 50 subjects in the age group between 21 to 24 years to estimate stature from percutaneous length of ulna at department of Anatomy, Nimra Institute of Medical Sciences, Andhra Pradesh. This study revealed that mean height was 165.72 ± 3.95 cm and mean length of right ulna was 29.84 ± 2.03 cm; and mean length of left ulna was 29.78 ± 2.04 cm for males. In females, mean height was 160.58 ± 3.52 cm and mean length of right ulna was 26.70 ± 0.73 cm and left ulna was 26.63 ± 0.73 cm. Males have positive correlation of 0.93 between height and length of ulna (the same for right and left). In females also, correlation between height and length of ulna was 0.63 for right ulnar length and 0.61 for left ulnar length (40).

A similar study was done on 300 students (150 males and 150 females) in the age group 21 to 25 years to estimate stature from ulnar length in various institutions of H.K.E. Society, Gulbarga. In this study, a positive correlation between height and ulnar length was observed in both sexes and it was statistically significant. The correlation coefficient was 0.653 for right ulna and 0.671 for left ulna in males. In case of females, the correlation coefficient was 0.641 for right ulna and 0.689 for left ulna. Regression equation for stature estimation was formulated using ulnar length for both sexes (41).

Another study was conducted among 90 school-age children (45 males and 45 females) in the age group 5 to 19 years to determine stature from ulnar length in central region of Thailand. The findings of this study showed bilateral asymmetry in right and left ulnar length of both sexes which was not statistically significant. There was statistically significant correlation between stature and forearm measurements ($P < 0.001$). The correlation coefficient between stature and forearm length (ulna) was higher in males. For males, the correlation coefficients by both sides of ulnar length was $r = 0.990$. For females, the correlation coefficients by both sides of ulnar length was $r = 0.988$. It was also observed that correlation coefficients, coefficients of determination, and standard errors of estimate of multiple regression equations are better than those of linear regression equations (18).

A study was conducted to determine stature from ulnar length among 50 medical female students in the age group 19 to 24 years in Kermanshah University, Iran. In this study, mean length of right ulna was 25.604 ± 0.161 cm and left ulna was 25.361 ± 0.163 cm. Right ulnar length was significantly longer than left ulnar length ($p < 0.05$). The correlation coefficient (R) between height and ulnar length was 0.753 for right ulna and 0.731 for left ulna respectively (16).

A similar study was carried out to estimate stature from ulnar length among 100 medical students (50 males and 50 females) in the age group 19 to 35 years studying at Regional Institute of Medical Sciences, Nagaland. The mean stature of males was 168.12 ±5.48 cm and females was 157.0 ±5.4 cm. Mean length of right and left ulna in males were 27.45±1.21 cm and 27.42 ± 1.24 cm respectively and that of females were 25.15±1.29 cm and 25±1.29 cm respectively. Comparisons between right and left sides were insignificant in both sexes ($P > 0.05$). The correlation coefficient (r) between stature and ulnar length for males and females were 0.629 and 0.787 respectively (14).

Another similar study was conducted to estimate stature from ulnar length among 300 medical male students in the age group 20 to 23 years of Vinayaka Mission's University in south India. The correlation coefficient (r) of height and length of right ulna was 0.689 and left ulna was 0.790. Pearson's correlation coefficient was statistically significant ($P<0.05$) (15).

2.8. Correlation of hand length and hand breadth with stature

A study was conducted on 200 students and staffs (100 males and 100 females) in the age group 17 to 30 years in North India showed that mean height and standard deviation of males was 170.71 ± 8.51 cm and for females, mean height and standard deviation was 161.6 ±7.62 cm. The mean right hand length for males was 19.59 ±1.12 cm and for females was 19.67 ± 1.14 cm. The correlation coefficient of right hand length with stature was 0.608 for males and 0.658 for females (11).

Another study was conducted on 30 males and 30 females in the age group 18 to 60 years in north India revealed that mean stature and hand length in males was higher as compared to that of females. There was no bilateral difference in hand length for both sexes (42).

A study was carried out on 600 School Children in the age group 5 to 10 years in Nigeria showed that correlation coefficient between height and hand length for males was 0.706 and for females was 0.703. There was no significant difference between right and left hand length for males and females. The simple linear regression and multiple linear regression equations for estimation of height from hand length showed a positive correlation ($p \leq 0.001$) with height (43).

A study was done on 268 adults (158 men and 110 women) in the age group 20 to 39 years in West Bengal, India revealed that mean height and hand length and hand breadth were higher in men than women with significant gender difference ($p<0.001$). The correlation coefficient (r) of hand length with stature for males was 0.53 for right hand length and 0.56 for left hand length. For hand breadth in males was also $r = 0.31$ and $r = 0.3$ for right and left hand breadth respectively. Similarly in females, the correlation coefficient (r) of hand length with stature was 0.51 for right hand length and 0.49 for left hand length. For hand breadth in females was also $r = 0.36$ and $r = 0.36$ for right and left hand breadth respectively (44).

2.9. Correlation of tibial length with stature

A study was conducted on 40 males and 40 females in the age group 18 to 30 years in central India revealed that mean height of study subjects was 163.46 ± 9.70 cm. The mean lengths of right tibia and left tibia were 37.33 ± 2.94 and 37 ± 2.88 cm respectively. The correlation coefficient (r) of right and left tibial lengths were 0.886 and 0.864 respectively (45).

Another study was conducted on 400 subjects (200 male and 200 female) in the age group 17 to 24 years in India revealed that correlation coefficient of 0.86 for males and 0.85 for females. The R-square value for males was 0.74 and for females was 0.72. The relationship between body height and percutaneous tibial length was statistically significant ($P<0.05$) in males and females (1).

A study was also carried out on 540 students (270 Males and 270 females) in the age group 18 to 21 years in Gwalior showed that there was no significant difference ($p>0.05$) in percutaneous length of right and left tibia in males and females. The mean length of tibia for males was 38.24 cm and for females was 36.06 cm. The mean height was 164.5 cm and 155.3 cm for males and females respectively. The correlation coefficients of height and tibial length for males and females were 0.43 and 0.60 respectively (4).

A study was done in various senior secondary schools and colleges of Naraingarh in India revealed that males were taller and their mean percutaneous lengths of tibia were significantly greater than that of females. This study also showed that overall bilateral differences were not significant in both sexes (46).

A similar study was also conducted on 518 cadavers between 23 to 75 years of age revealed a good correlation of stature with tibial length and it was statistically highly significant (5).

2.10. Correlation of foot length and foot breadth with stature

A study was conducted on 640 students (343 males and 297 females) in the age group 18 to 23 years in Nagpur revealed that males have greater mean value of stature than females. In males, mean value of right foot length was 27.14 ± 1.16 cm and left foot length was 27.2 ± 1.16 cm. In females, mean value of right foot length was 24.26 ±1.43 cm and left foot length was 24.32 ±1.43 cm. In males, mean value of right foot breadth was 10.49 ± 0.52 cm and left foot breadth was 10.55 ± 0.52 cm. In females, mean value of right foot breadth was 9.34 ± 0.54 cm and left foot breadth was 9.4 ± 0.54 cm. There was a positive correlation between stature and foot length and foot breadth in both sexes (47).

Another study was conducted on 1000 medical students (536 males and 464 Females) in the age group 19 to 22 years in Maharashtra showed that foot length in both sexes depicts higher correlation coefficients with stature (r = 0.85) than hand length and head length. Estimation of stature using foot length, hand length and head length gave multiple correlation coefficient 'R' for both sexes together, which was higher (R = 0.879) than values obtained through single parameter (12).

Another similar study was also carried out on 104 individuals (54 males and 50 females) in the age group 21 to 35 years in Secunderabad revealed that mean height of males was 170.98 ± 6.65 cm and females was 157.65 ± 6.6 cm. The correlation coefficient was 0.58 for right foot length and 0.59 for left foot length in males. In females, the correlation coefficient was 0.66 for right foot length and 0.65 for left foot length (2).

A study was carried out on 300 medical students (147 males and 153 females) to evaluate correlation between stature and hand length, hand width, foot length, foot width, forearm length and knee-to-ankle length in Mumbai. It was found that foot length revealed the second highest correlation with stature (r = 0.6102). In this study, among lower extremity measurements, foot length (r = 0.6102) was found to be best estimator of stature (48).

A study was done among 160 adults in the age group 20 to 50 years in Gujarat to estimate stature from shoulder width, arm length and foot length. The correlation coefficient of foot length with stature was 0.709 for males and 0.081 for females (39).

3. OBJECTIVES OF THE STUDY

3.1. 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 of Debre Markos University.

3.2. 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
- To develop regression models to predict height using these anatomical anthropometric parameters.
- 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.

4. MATERIALS AND METHODS

4.1. Study Area

The study was conducted in Debre Markos University, East Gojam zone, Amhara Regional state, Ethiopia. Debre Markos (also called Mankorer) is a city and woreda in North West Ethiopia. It is located in East Gojam Zone, Amhara regional state, Ethiopia. It has an elevation of 2,446 meters and 299 kilometers from Addis Ababa, capital city of Ethiopia and 265 kilometers from Bahir Dar, capital city of Amhara regional state. Debre Markos University is Public University located in Debre Markos town and two kilometers far from central square of the town in the east. It was started in 2005 as one of thirteen universities that were established by federal democratic republic government of Ethiopia. Currently the university has six colleges, two schools, two institutions and 42 departments; and a total of 27,303 students were involved in different programs.

4.2. Study Period

The study was conducted from April, 2018 to June, 2018 G.C.

4.3. Study Design

Institution based descriptive cross-sectional prospective study was conducted in Debre Markos University students.

4.4. Source Population

All regular undergraduate students in Debre Markos University.

4.5. Study Population

All first year regular undergraduate students in Debre Markos University who fulfill the inclusion criteria.

4.6. Sample Size Determination

The sample size was determined statistically, within 95 % level of confidence and 5 % margin of error, using the following single population proportion formula:

$n = Z^2P(1-P)/d^2$

n = the sample size to calculated

Z = level of confidence interval, 95%

P = proportion of the event to be studied

D = margin of error, 5%

The value of proportion (p) was taken as 50% because no study was conducted in the study population. Therefore Z =1.96 (95%), P = 0.5 (50%), d = 0.05 (5%).

$n = Z^2P(1-P)/d^2$

$n = (1.96)^2 \times 0.5(1-0.5) / (0.05)^2$

n = 384

However, samples was taken from a relatively small population (N = 3579) which was less than 10,000. Therefore, the above calculated sample size (n = 384) was adjusted by using correcting sample size formula as follows:

$$n1= \frac{N \times n}{N+n}$$

n1 = corrected sample size

N = the size of source population = 3579 (source: registrar office of DMU)

Male = 2125, Female = 1454.

N = 3579.

n = non-corrected sample size =384

$$n1= \frac{3579 \times 384}{3579+384} = 347$$

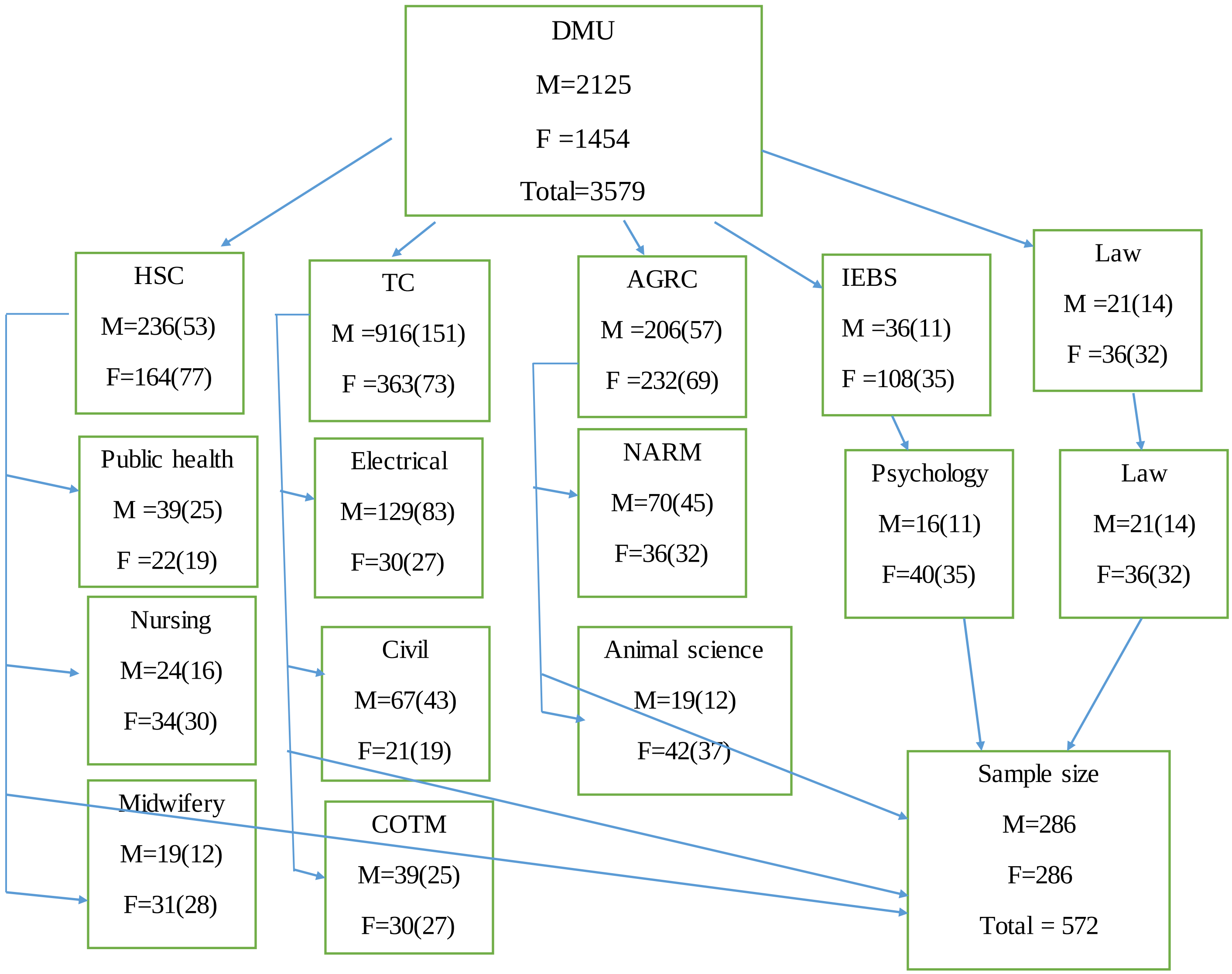
n1=347.

n1 =347 x 1.5 (design effect) = 520

Approximately 520 students + 10% non-respondent rate = 572 students were included in the study.

4.7. Sampling Procedure

Multi-stage sampling method was used to select samples who fulfill inclusion criteria. Debre Markos University has six colleges, two schools and two institutions. The primary sampling units (PSU) were selected by lottery method as colleges, schools and institutions. Secondary sampling units (SSU) were also selected by lottery method from primary sampling units as departments. The tertiary sampling units (TSU) were students and selected by simple random sampling method according to inclusion criteria. The PSUs were Health Science College, Technology College, Agriculture and Natural Resource College, School of law and Institution of Education and Behavioral Sciences. The SSUs were departments as Public health, Nursing, Midwifery, Civil Engineering, Electrical Engineering, Construction management, Natural Resource Management, Animal Science, Psychology and school of law. The TSUs were students and interviewed and measured according to inclusion criteria until the desired sample size was attained. The number of male and female students were proportional from the total sample size, 572. Therefore, the number of male students were 286 and number of female students were 286. The proportional selection of students from each colleges, schools and departments is provided in figure 1.



M = male, F = Female, HSC = Health Science College, TC = Technology college, AGRC = Agriculture and Natural resource College, IEBS = Institution of Education and Behavioral Science, NARM = Natural Resource Management, COTM = Construction Management.

Figure 1: Proportion of male and female respondents in Debre Markos University, North West Ethiopia, 2018

4.8. Inclusion and Exclusion Criteria

4.8.1. Inclusion Criteria

All first year regular undergraduate students in the University without any obvious congenital or acquired deformity of spine, extremities, head; and voluntary to participate in the study were included.

4.8.2. Exclusion Criteria

- Students who had deformity of the skull.
- Students who had deformity of shoulder and arm.
- Students who were having any significant growth disorders of forearm and hand.
- Students who were having deformities of spine and extremities.
- Students who were having deformity and anomaly of leg and foot; and
- Bony anomalies and fractures of forearm and hand were excluded from study group.

4.9. Study Variables

4.9.1. Dependent Variable

- ✓ Stature/height

4.9.2. Independent Variables

- ✓ Age
- ✓ Sex
- ✓ Weight
- ✓ Head circumference
- ✓ Head length
- ✓ Humeral length
- ✓ Inter-acromial length
- ✓ Ulnar length
- ✓ Hand length
- ✓ Hand breadth
- ✓ Tibial length
- ✓ Foot length
- ✓ Foot breadth

4.10. Operational Definitions

Stature: It is a natural heights of a person in an upright position (14).

Vertex: It is the highest point on the head in the mid-sagittal plane (30).

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.

Frankfurt horizontal plane: The plane passing through the lowest points on the infra-orbital margins and the tragion (the notch immediately above the tragus of the ear), which is obtained when the subject is looking straight ahead of him (30).

Glabella: The most prominent point on the frontal bone above the root of the nose, between the eyebrows (30).

Opisthocranion: The most projecting point on the dorsal surface of the head in the mid-sagittal plane (30).

Head circumference: It is just above the supercilliary arch on the anterior aspect, just above the auricle on the lateral aspect and at the level of external occipital protuberance on posterior aspect (19).

Head length: The distance between the glabella and farthest projecting point in the mid-sagittal plane, on back of the head (Occiput) (8).

Inter-acromial length: The distance between two bony landmarks, i.e. acromial process of scapula on each side (35).

Humeral length: The length of humerus was defined as the distance between acromion end of clavicle and olecranon process (37).

Ulnar length: From tip of olecranon process to the distal margin of the head of ulna (9).

Hand length: From middle of the distal wrist crease to the distal end of most projecting point of hand (10).

Hand breadth: The maximum distance between the radial sides of 2nd metacarpophalangeal joint to the ulnar side of 5th metacarpophalangeal joint (32).

Tibial length: The distance between the medial most superficial point on upper border of medial condyle of tibia and tip of medial malleolus (28).

Foot length: The maximum length between the most prominent posterior point of the heel and the tip of hallux and the tip of the second toe if it is larger than the hallux (11).

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 was fully stretched (29).

4.11. Data Collection Instruments

- Self-prepared structured questionnaire,
- Weight scale and Stadiometer
- Non elastic measuring tape meter and
- Sliding caliper

4.12. Methods of Data Collection

Self-prepared structured questionnaire was designed to collect data of socio demographic and other related variables. The following anthropometric variables of the study subjects were measured:

- Standing height
- Weight
- Head circumference and head length
- Inter-acromial length
- Humeral length
- Ulnar length
- Hand length and hand breadth
- Tibial length
- Foot length and foot breadth.

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, having palms of hands turn inward and fingers pointing down wards. It was measured from sole of feet to vertex of head as recommended by International biological program (49). Weight was measured with standard mechanical balance.

Head circumference was measured by non-elastic measuring tape meter which encircle head just above supercilliary arch on anterior aspect, just above auricle on lateral aspect and at the level of external occipital protuberance on posterior aspect in centimeter (31). Head length was measured by non-elastic measuring tape meter from the distance between glabella and farthest projecting point in the mid-sagittal plane, on back of the head (Occiput). The latter is termed as Opisthocranion (9).

Inter-acromial length was measured with measuring tape meter as the distance between two bony landmarks, i.e. acromial process of scapula on each side. Acromion is the most lateral point on the lateral margin of acromial process when the subject stands in anatomical position with his arms hanging by the sides (33).

Humeral length was measured with measuring tape meter in 90 degrees bended elbow in persons with standing position. The length of arm is defined as the distance between acromion end of clavicle and olecranon process (37).

The ulnar length was measured using measuring tape meter from tip of olecranon process to the distal margin of head of ulna (palpable on dorsum of wrist) with forearm flexed and semi pronated and the hand in neutral position (10).

Hand length was measured with non-elastic measuring tape meter from middle of distal wrist crease to distal end of most projecting point of hand (11). Hand breadth was measured as the maximum distance between radial side of 2^{nd} metacarpophalangeal joint to ulnar side of 5^{th} metacarpophalangeal joint (50).

Tibial length was measured with non-elastic measuring tape meter as the distance between medial most superficial point on upper border of medial condyle of tibia and tip of medial malleolus (45).

Foot length was measured with non-elastic measuring tape meter as the maximum length between the most prominent posterior point of heel and the tip of hallux and the tip of the second toe if it is larger than the hallux (12). Foot breadth was measured as a straight distance from metatarsale tibial (the most medially placed point on head of first metatarsal) and metatarsale fibulare (the most laterally placed point on head of fifth metatarsal) when the foot was fully stretched (47).

4.13. Data Quality Control

The data was collected by three personnel. The principal investigator and other two persons, one male (BSc public health officer) and one female (BSc midwifery). To maintain data quality, training was given for data collectors. Properly designed data collection materials were prepared. Supervision was carried out by the principal investigator during data collection times to check completeness and consistency to keep the quality of the data. The reliability and representativeness of data was maintained by incorporating only complete data of study subjects with in the study period.

4.14. Data Processing and Analysis

Data was checked after collection from each participant for its completeness. The data was entered in EPI data version 3.1 and analyzed using SPSS version 25 statistical software. The correlation among different anatomical anthropometric measurements with height was tested. P-value less than 0.05 was taken as statistically significant. Correlation coefficients were calculated and linear regression equations were formulated to estimate stature from measurements taken. Fitness of regression models were assessed using coefficients of determination and residual plots. Multicollinearity was also assessed using Durbin Watsons test and variance inflation factor (VIF) with equal variance assumption. Gender difference among different anatomical anthropometric measurements were assessed. The data was presented by using statements, tables, charts and graphs.

4.15. Ethical Considerations

Ethical clearance was obtained from post graduate office of Anatomy, College of Heath Sciences, Addis Ababa University. Permission was obtained from research directorate of Debre Markos University. The purpose and importance of the study was explained to each study participant and I informed them no personal identifiers were used the data; and verbal consent was obtained from each participant. Participants had right to be excluded from study if they were not voluntary to participate.

4.16. Result Disseminations

Results of the study would be disseminated to Addis Ababa University, public Health research and emergency management core process, postgraduate research office of Anatomy and department of Biomedical Sciences in Debre Markos University. Finally it would be attempted to disseminate in reputable journals for publication.

5. RESULTS

5.1. Descriptive statistics of sociodemographic Variables

A total of 572 students were included in the study. Out of these, 286 (50%) respondents were males and 286 (50%) respondents were females. Majority of respondent's age, 301 (52.7%), ranged from 18 to 20 years with mean age of 21.27±1.74 and 20.41±1.58 for males and females respectively. About 405 (70.8%) and 167 (29.2%) respondents came from rural and urban areas respectively. From total respondents, 319 (55.8%), 123 (21.5%), 26 (4.5%) and 10 (1.7%) came from Amhara, Oromia, SNN and Tigray regions respectively. Majority of respondents were Amhara (57.9%) followed by Oromo (22.0%).

Table 1: Sociodemographic characteristics of respondents in Debre Markos University, North West Ethiopia, 2018

Variables	Categories	Frequencies	Percentages (%)
Sex	Male	286	50.0%
	Female	286	50.0%
Age	18-20	301	52.7%
	21-23	208	36.4%
	24-26	63	10.9%
Residence	Urban	167	29.2%
	Rural	405	70.8%
Region	Amhara	319	55.8%
	Oromia	123	21.5%
	SNN	26	4.5%
	Tigray	10	1.7%
	Others	94	15.4%
Ethnicity	Amhara	331	57.9%
	Oromo	126	22.0%
	SNN	28	4.9%
	Tigray	14	2.4%
	Others	73	12.8%

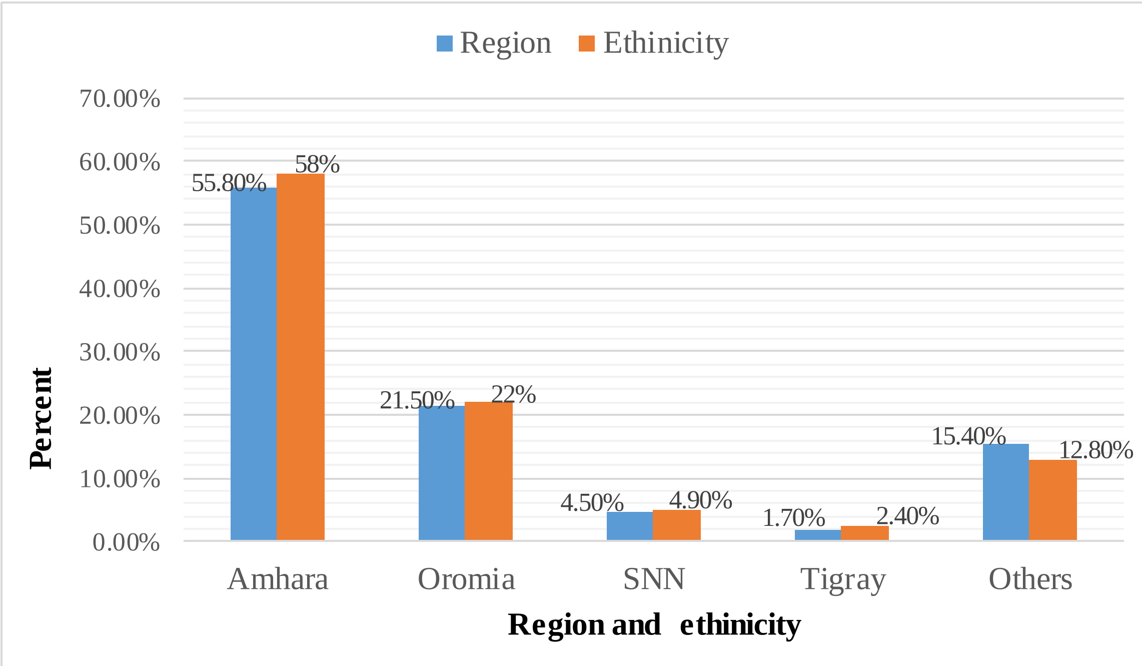


Figure 2: Region and ethnicity of respondents in Debre Markos University, North West Ethiopia, 2018

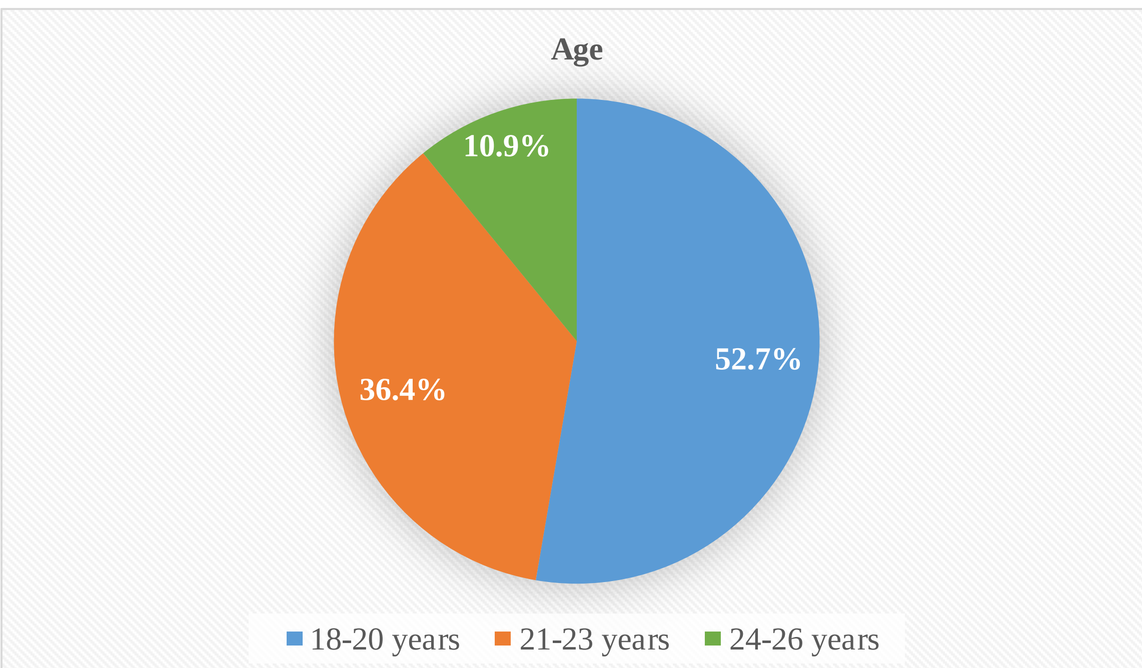


Figure 3: Age distribution of respondents in Debre Markos University, North West Ethiopia, 2018

5.2. Descriptive statistics of anatomical anthropometric parameters of study participants

Descriptive statistics for height, weight, body mass index and anatomical anthropometric measurements of male participants is provided in table 2. It was observed that height ranged from 155.0 cm to 182.0 cm and mean height was 168.36 ± 5.89 cm in male participants. In male participants, it was also observed that weight ranged from 45 kilogram (kg) to 75 kilogram and mean weight was 59.23± 6.39 kg. The minimum and maximum body mass index of males were 16.32 kg/m^2 to 27.35 kg/m^2 respectively. The mean body mass index was 20.86 ± 1.55 kg/m^2 (Table 2).

Table 2: Descriptive statistics of height, anatomical anthropometric measurements, weight and body mass index of male participants in Debre Markos University, North West Ethiopia, 2018

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
RT humeral length	28.5	39.5	33.09	1.93
LT humeral length	28.5	39.5	33.12	1.93
RT ulnar length	21.1	33.0	25.74	1.56
LT ulnar length	21.2	32.9	25.79	1.56
RT hand length	15.1	18.1	17.22	0.47
LT hand length	15.1	18.2	17.25	0.47
RT hand breadth	6.1	8.8	7.54	0.49
LT hand breadth	6.2	8.9	7.57	0.49
RT tibial length	28.1	45.0	37.05	3.27
LT tibial length	28.2	45.0	37.09	3.26
RT foot length	18.5	25.0	22.06	1.61
LT foot length	18.5	25.0	22.08	1.60
RT foot breadth	7.1	10.1	8.75	0.61
LT 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

RT = right, LT = left, cm = centimeter

BMI = body mass index

Majority of male participants, 271 (94.76%), had normal body mass index (18.5 to 24.9 kg/m^2) whereas about 14 (4.9 %) and 1 (0.34%) of male participants were underweight and overweight respectively (51).

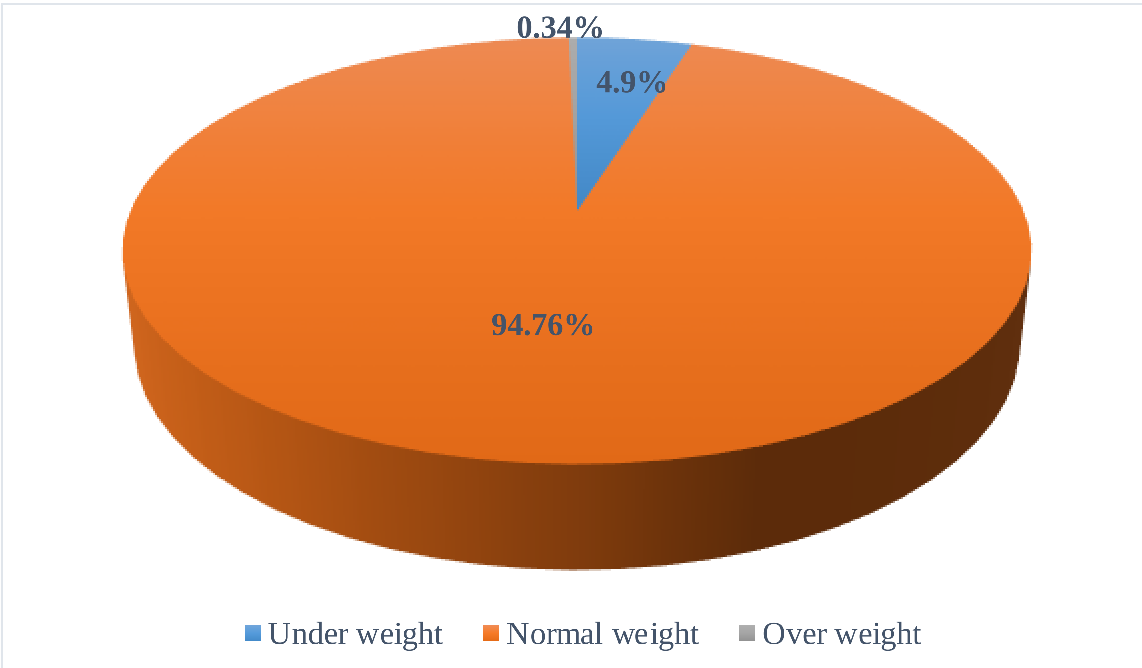


Figure 4: Categories of body mass index for male participants in Debre Markos University, North West Ethiopia, 2018

Descriptive statistics for height, weight, body mass index and anatomical anthropometric measurements of female participants is provided in table 3. It was observed that height ranged from 153.0 cm to 178.8 cm and mean height was 165.24 ± 4.01 cm for female participants. In females, it was also observed that weight ranged from 44 kilogram (kg) to 76 kilogram and mean weight was 54.86 ± 6.16 kg. The minimum and maximum body mass index (BMI) of female participants were 15.51 kg/m^2 and 30.25 kg/m^2 respectively. The mean BMI for females was 20.08 ± 2.06 kg/m^2. The mean head circumference of female participants was 53.34 ± 2.95 cm. The mean right and left humeral lengths of female participants were 31.83 ± 1.91 cm and 31.87 ±1.92 cm respectively (Table 3).

It was also observed that mean right and left tibial lengths of females were 34.88 ± 3.37 cm and 34.91±3.36 cm respectively. The mean right and left foot lengths of female participants were also 20.97 ± 1.45 cm and 20.99 ± 1.46 cm respectively (Table 3).

Table 3: Descriptive statistics of height, anatomical anthropometric measurements, weight and body mass index of female participants in Debre Markos University, North West Ethiopia, 2018

Parameters (cm)	Minimum	Maximum	Mean	Standard deviation(SD)
Stature/height	153.0	178.8	165.24	4.014
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
RT humeral length	27.5	36.5	31.83	1.91
LT humeral length	27.8	36.5	31.87	1.92
RT ulnar length	21.2	29.1	24.75	1.48
LT ulnar length	21.3	29.2	24.79	1.49
RT hand length	15.0	18.1	17.03	0.54
LT hand length	15.0	18.1	17.02	0.53
RT hand breadth	6.0	8.5	7.15	0.58
LT hand breadth	6.0	8.7	7.17	0.59
RT tibial length	28.1	41.8	34.88	3.37
LT tibial length	28.2	41.9	34.91	3.36
RT foot length	18.0	24.1	20.97	1.45
LT foot length	18.0	24.2	20.99	1.46
RT foot breadth	6.5	10.1	8.14	0.78
LT foot breadth	6.5	10.3	8.18	0.79
Weight	44	76	54.86	6.16
BMI	15.51	30.25	20.08	2.07

RT = right, LT = left, cm = centimeter

BMI = body mass index

Majority of female participants, 219 (76.6%), had normal body mass index (18.5 to 24.9 kg/m^2) whereas 62 (21.7 %), 4 (1.4%) and 1(0.3%) of females were underweight, overweight and obese respectively (figure 5).

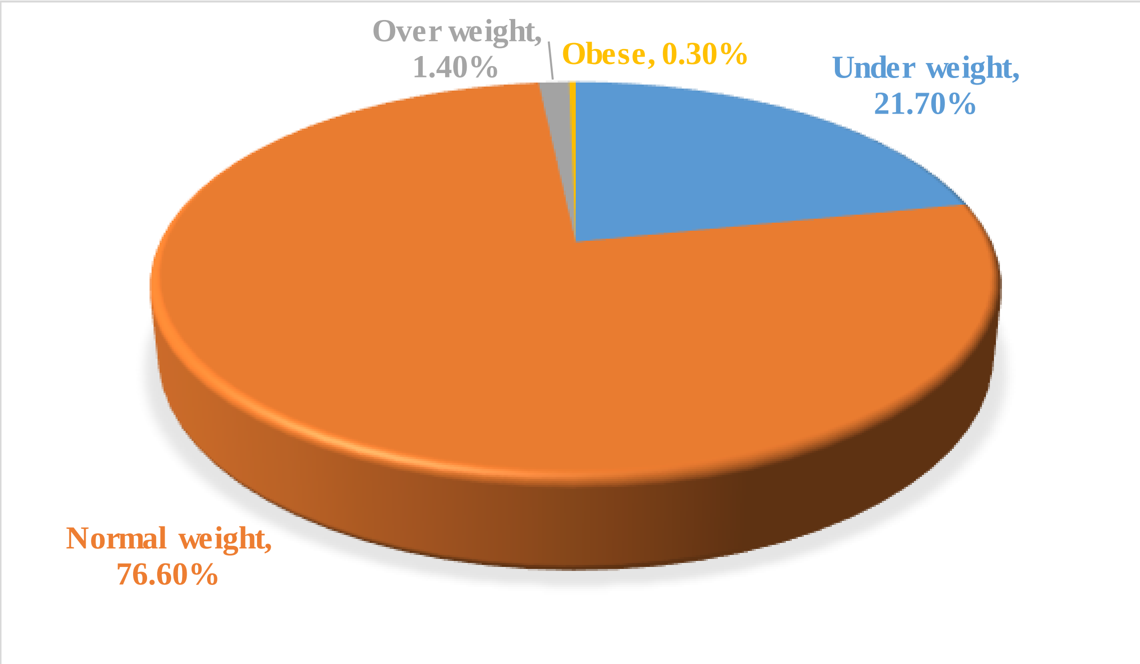


Figure 5: Categories of body mass index for female participants in Debre Markos University, North West Ethiopia, 2018

5.3. Height and anatomical anthropometric measurement difference in males and females

Strength of gender difference in height and anatomical anthropometric measurements was assessed using independent (unpaired) sample t-test. Table 4 illustrates comparison of mean value of height, weight, BMI and anatomical anthropometric measurements between male and female participants. It was evident that overall mean value of height and all anatomical anthropometric measurements of male participants were greater than that of females and all these differences were statistically significant ($p < 0.05$) (Table 4).

Table 4: Comparison of means of all measurements between male and female participants in Debre Markos University, North West Ethiopia, 2018

Parameters (cm)	Un paired t – test for equality of means						
						95% CI	
	T	DF	Sig.	MD	SED	Lower	Upper
Stature/height	7.400	570	.001	3.121	.4218	2.292	3.949
Head circumference	4.862	570	.001	1.203	.2475	.7173	1.689
Head length	5.769	570	.001	.7633	.1323	.5034	1.023
Inter-acromial length	5.834	570	.001	.7332	.1257	.4864	.9801
RT humeral length	7.843	570	.001	1.259	.1606	.9440	1.574
LT humeral length	7.818	570	.001	1.253	.1604	.9388	1.568
RT ulnar length	7.759	570	.001	.9881	.1273	.7380	1.238
LT ulnar length	7.888	570	.001	1.004	.1273	.7544	1.254
RT hand length	5.047	570	.001	.1955	.0387	.1194	.2715
LT hand length	6.126	570	.001	.2360	.0385	.1603	.3117
RT hand breadth	8.706	570	.001	.3881	.0446	.3006	.4757
LT hand breadth	8.810	570	.001	.4003	.0454	.3111	.4896
RT tibial length	7.814	570	.001	2.167	.2774	1.622	2.712
LT tibial length	7.843	570	.001	2.170	.2768	1.627	2.714
RT foot length	8.536	570	.001	1.095	.1283	.8431	1.347
LT foot length	8.535	570	.001	1.092	.1280	.8412	1.344
RT foot breadth	10.43	570	.001	.6105	.0585	.4955	.7255
LT foot breadth	10.38	570	.001	.6133	.0591	.4972	.7293
Weight	8.319	570	.001	4.367	.525	3.336	5.398
BMI	5.067	570	.001	.7735	.1526	.4736	1.073

T = t-statistics, DF = degree of freedom, MD = mean difference, SED = standard error of difference, CI = confidence interval. Sig. = significance (<0.05), cm = centimeter

5.4. Assessment of bilateral asymmetry of right and left anatomical anthropometric measurements

The presence of bilateral asymmetry between right and left anatomical anthropometric measurements were assessed for male and female participants by using paired sample t-test. All bilateral anatomical anthropometric measurements in male participants exhibited statistically significant bilateral asymmetry such as for humeral length ($t = -5.714$, $p < 0.05$) and ulnar length (t = -9.654, p<0.05). The mean value of all bilateral anatomical anthropometric measurements in males were significantly higher on the left side than the right side (Table 5).

Table 5: Bilateral asymmetry of anatomical anthropometric measurements of male participants in Debre Markos University, North West Ethiopia, 2018

Bilateral parameters (cm)	Paired sample t-test for males							
				95% CI				
	MD	SD	SED	Lower	Upper	T	DF	Sig.
RHuL-LHuL	-.0294	.0869	.0051	-.0395	-.0193	-5.714	285	.001
RUL-LUL	-.0521	.0913	.0054	-.0627	-.0415	-9.654	285	.001
RHL-LHL	-.0318	.0790	.0047	-.0410	-.0226	-6.808	285	.001
RHB-LHB	-.0332	.0743	.0044	-.0419	-.0246	-7.558	285	.001
RTL-LTL	-.0353	.0806	.0048	-.0447	-.0259	-7.406	285	.001
RFL-LFL	-.0199	.0659	.0039	-.0276	-.0123	-5.117	285	.001
RFB-LFB	-.0441	.0750	.0044	-.0528	-.0353	-9.929	285	.001

SD = standard deviation, RHuL = right humeral length, LHuL = left humeral length, RUL = right ulnar length, LUR = 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.

All bilateral anatomical anthropometric measurements in female participants exhibited statistically significant bilateral asymmetry such as for hand length (t = 3.906, p< 0.05) and for foot length (t = -5.330, p<0.05). Except hand length, mean value of all bilateral anatomical anthropometric measurements in female participants were significantly higher on left side than right side (Table 6).

Table 6: Bilateral asymmetry of anatomical anthropometric measurements of female participants in Debre Markos University, North West Ethiopia, 2018

Bilateral parameters (cm)	Paired sample t-test for females							
				95% CI				
	MD	SD	SEE	Lower	Upper	T	DF	Sig.
RHuL-LHuL	-.0350	.0819	.0048	-.0445	-.0254	-7.222	285	.001
RUL-LUL	-.0357	.0767	.0045	-.0446	-.0267	-7.865	285	.001
RHL-LHL	.0087	.0378	.0022	.0043	.0131	3.906	285	.001
RHB-LHB	-.0210	.0625	.0037	-.0283	-.0137	-5.674	285	.001
RTL-LTL	-.0325	.0751	.0044	-.0413	-.0238	-7.322	285	.001
RFL-LFL	-.0224	.0710	.0042	-.0306	-.0141	-5.330	285	.001
RFB-LFB	-.0413	.0752	.0044	-.0500	-.0325	-9.274	285	.001

5.5. Correlation between height and anatomical anthropometric measurements

Pearson's correlation coefficient (R) between height and anatomical anthropometric measurements for male and female participants is provided in Table 7. The R-value between height and all anatomical anthropometric measurements ranged from 0.243 to 0.634 for male participants and from 0.035 to 0.259 for female participants. All anatomical anthropometric measurements and weights of male participants showed positive and statistically significant R value with height ($p < 0.05$). Except right and left foot breadths, all anatomical anthropometric measurements and weights of female participants showed positive statistically significant R value with height ($p < 0.05$). For both males and females, the highest correlation was depicted in right tibial length. However lowest correlation was exhibited in left hand length and left foot breadth for male and female participants respectively. The BMI of males and females revealed statistically insignificant correlation with height ($p > 0.05$). The R- value for all anatomical anthropometric parameters was greater in male participants than that of females (Table 7).

Table 7: Correlation of height with anatomical anthropometric measurements, weight and body mass index of male and female participants in Debre Markos University, North West Ethiopia, 2018

	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)

The strength of association between height and weight of participants was greater than the association between height and other anatomical anthropometric parameters in both sexes (R = 0.725 for males, R = 0.406 for females). However body mass index (BMI), R = 0.113 for males and R = -0.034 for females, was not significantly correlated with height of males and females. For females, body mass index was negatively correlated with height even though it did not have significant association at P<0.05 (Table 7). Right tibial length, left tibial length and weight of participants showed highest significant association with height (P = 0.001) for males and females.

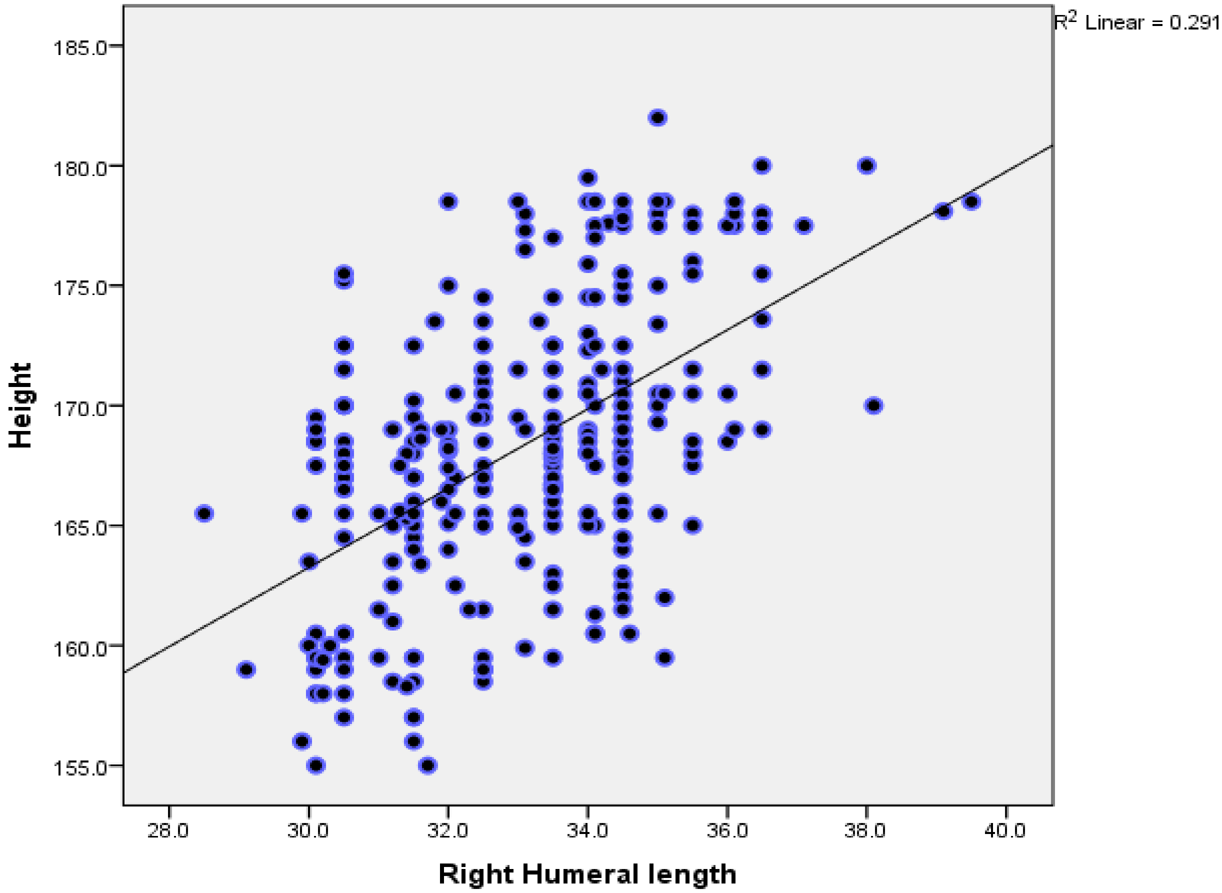


Figure 6: Scatter plot between height and right humeral length of male participants in Debre Markos University, North West Ethiopia, 2018

The fit line at the total revealed the relationship between height of male participants with their respective right humeral length and dispersion from the line at R^2 linear = 0.291 (Figure 6). The Pearson correlation coefficient between height and right humeral length of males was R = 0.539, P<0.05 (Table 7).

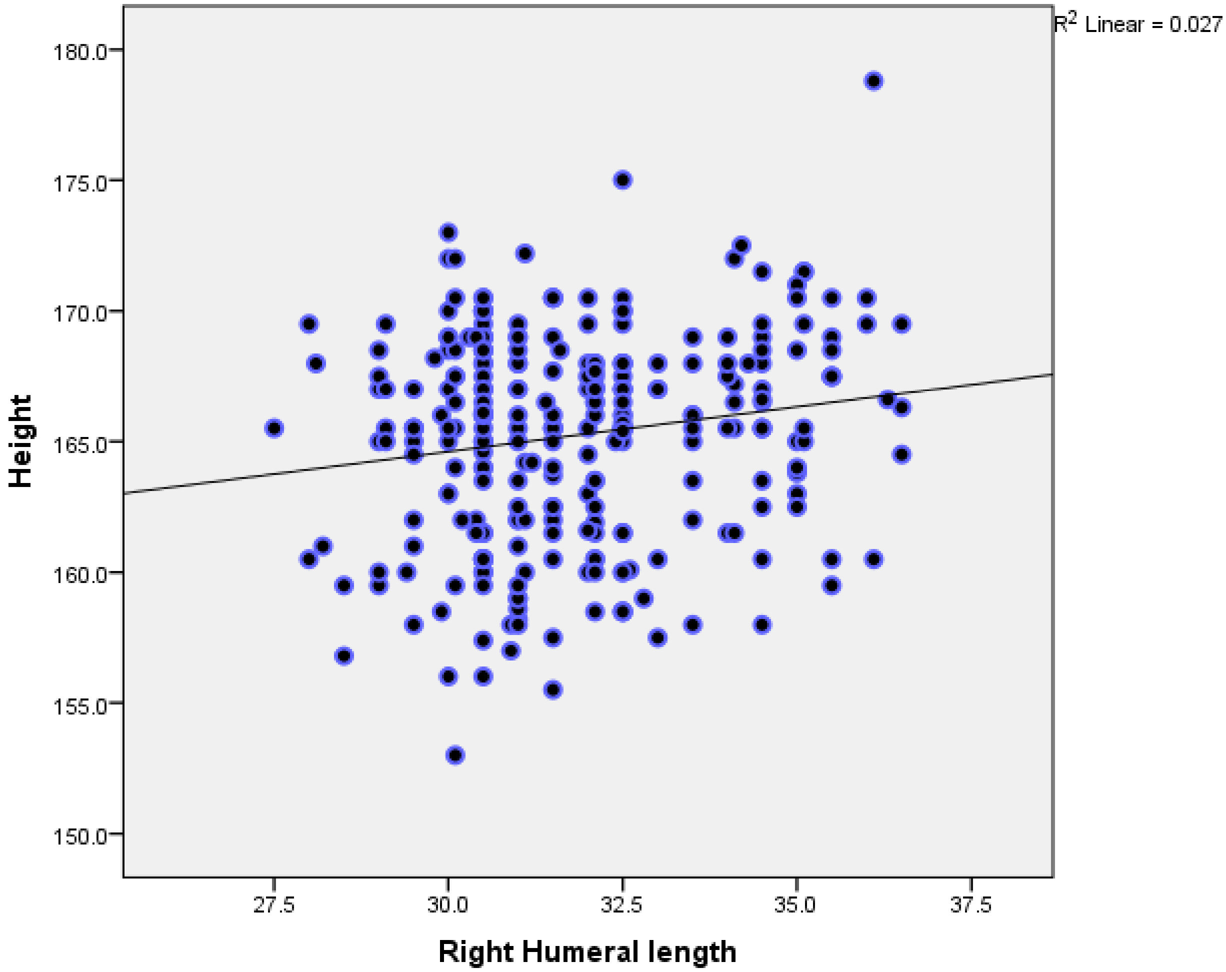


Figure 7: Scatter plot between height and right humeral length of female participants in Debre Markos University, North West Ethiopia, 2018

The fit line at the total showed the relationship between height of female participants with their respective right humeral length and dispersion from the line at R^2 linear = 0.027 (Figure 7). Pearson correlation coefficient between height and right humeral length of females were R = 0.163, $P<0.05$ (Table 7).

5.6. Stature estimation from anatomical anthropometric measurements

Multiplication factor, simple linear regression and multiple linear regression analyses were conducted to estimate height from each anatomical anthropometric measurements separately for both male and female participants.

5.6.1. Multiplication factors (MF) of each anatomical anthropometric measurements

Multiplication factors for each anatomical anthropometric measurements of male and female participants are provided in table 8. For instance mean multiplication factors for head circumference, right ulnar length, right hand length and right foot length in male participants were 3.09 cm, 6.56 cm, 9.78 cm and 7.66 cm respectively. Similarly mean multiplication factors for head circumference, right ulnar length, right hand length and right foot length in female participants were also 3.11 cm, 6.69 cm, 9.71 cm, and 7.92 cm respectively (Table 8).

Table 8: Multiplication factors for each anatomical anthropometric measurements of male and female participants in Debre Markos University, North West Ethiopia, 2018

	Males = 286		Females = 286	
Parameters (cm)	**Mean**	**MF**	**Mean**	**MF**
Head circumference	54.58	3.091	53.38	3.11
Head length	32.18	5.24	31.42	5.27
Inter-acromial length	35.18	4.79	34.44	4.81
RT humeral length	33.09	5.10	31.83	5.21
LT humeral length	33.12	5.09	31.86	5.20
RT ulnar length	25.74	6.56	24.75	6.69
LT ulnar length	25.79	6.54	24.78	6.70
RT hand length	17.22	9.78	17.03	9.71
LT hand length	17.25	9.76	17.02	9.72
RT hand breadth	7.54	22.42	7.15	23.26
LT hand breadth	7.57	22.32	7.17	23.20
RT tibial length	37.05	4.57	34.88	4.78
LT tibial length	37.09	4.57	34.91	4.78
RT foot length	22.06	7.66	20.97	7.92
LT foot length	22.08	7.65	20.99	7.91
RT foot breadth	8.75	19.32	8.14	20.48
LT foot breadth	8.79	19.23	8.18	20.38

5.6.2. Estimation of stature from each anatomical anthropometric parameters for male participants

Linear regression models were formulated for each anatomical anthropometric measurements to estimate stature for male participants. Estimation of statures from each anatomical anthropometric measurements of male participants are provided in table 9. The standard error of estimate (SEE) was ranged from 4.56 to 5.73 cm in all anatomical anthropometric measurements of males and the correlation coefficient (R) was also ranged from 0.243 to 0.634. The R-value was largest in RT tibial length and smallest in LT hand length. Whereas the smallest SEE value was observed in RT tibial length and largest value was in LT hand length (Table 9).

For instance, the regression model to estimate stature of male participants using their head circumference (HC) was 124.58 +0.80 HC with R = 0.404, R^2 = 0.163 and SEE = 5.40. The percentage of variability in association of HC and stature was 16.3%. The regression model to predict stature of male participants using right ulnar length (RUL) was also 120.13+1.87 RUL with R = 0.496, R^2 = 0.246 and SEE = 5.13. The percentage of variability accounted in the association of RUL and stature was 24.6%.

Regression models to estimate stature of male participants from right humeral length (RHuL), left humeral length (LHuL), right hand length (RHL), left hand length (LHL), right tibial length (RTL), left tibial length (LTL) ,right foot length (RFL) and left foot length (LFL) are expressed as follows (Table 9):

Stature = 113.77+1.65 RHUL

Stature = 114.10 +1.64 LHUL

Stature = 109.03+3.45 RHL

Stature = 115.74+3.05 LHL

Stature = 125.93+1.15 RTL

Stature = 125.93+1.14 LTL

Stature = 121.59+2.12 RFL

Stature = 121.17+2.14 LFL

Table 9: Estimation of stature from each anatomical anthropometric measurements of male participants in Debre Markos University, North West Ethiopia, 2018

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
RT humeral length	.539	.291	.288	4.97	113.77 + 1.65 RHUL	.001
LT humeral length	.535	.287	.284	4.98	114.10 +1.64 LHUL	.001
RT ulnar length	.496	.246	.244	5.13	120.13 +1.87RUL	.001
LT ulnar length	.498	.248	.246	5.12	119.68 +1.89 LUL	.001
RT hand length	.276	.076	.073	5.67	109.03 +3.45 RHL	.001
LT hand length	.243	.059	.056	5.73	115.74 +3.05 LHL	.001
RT hand breadth	.349	.122	.119	5.53	136.71+4.20 RHB	.001
LT hand breadth	.331	.110	.106	5.57	138.27+3.98 LHB	.001
RT tibial length	.634	.402	.400	4.56	125.93 +1.15 RTL	.001
LT tibial length	.632	.399	.397	4.57	125.93 +1.14 LTL	.001
RT foot length	.579	.336	.333	4.81	121.59 +2.12 RFL	.001
LT foot length	.581	.338	.335	4.80	121.17 +2.14 LFL	.001
RT foot breadth	.311	.096	.093	5.61	142.12 +3.00 RFB	.001
LT foot breadth	.306	.093	.090	5.62	142.35 +2.96 LFB	.001

RT = right, LT = left,

R = correlation coefficient, R^2 = coefficient of determination.

SEE = standard error of estimate,

Sig. = significance (<0.05)

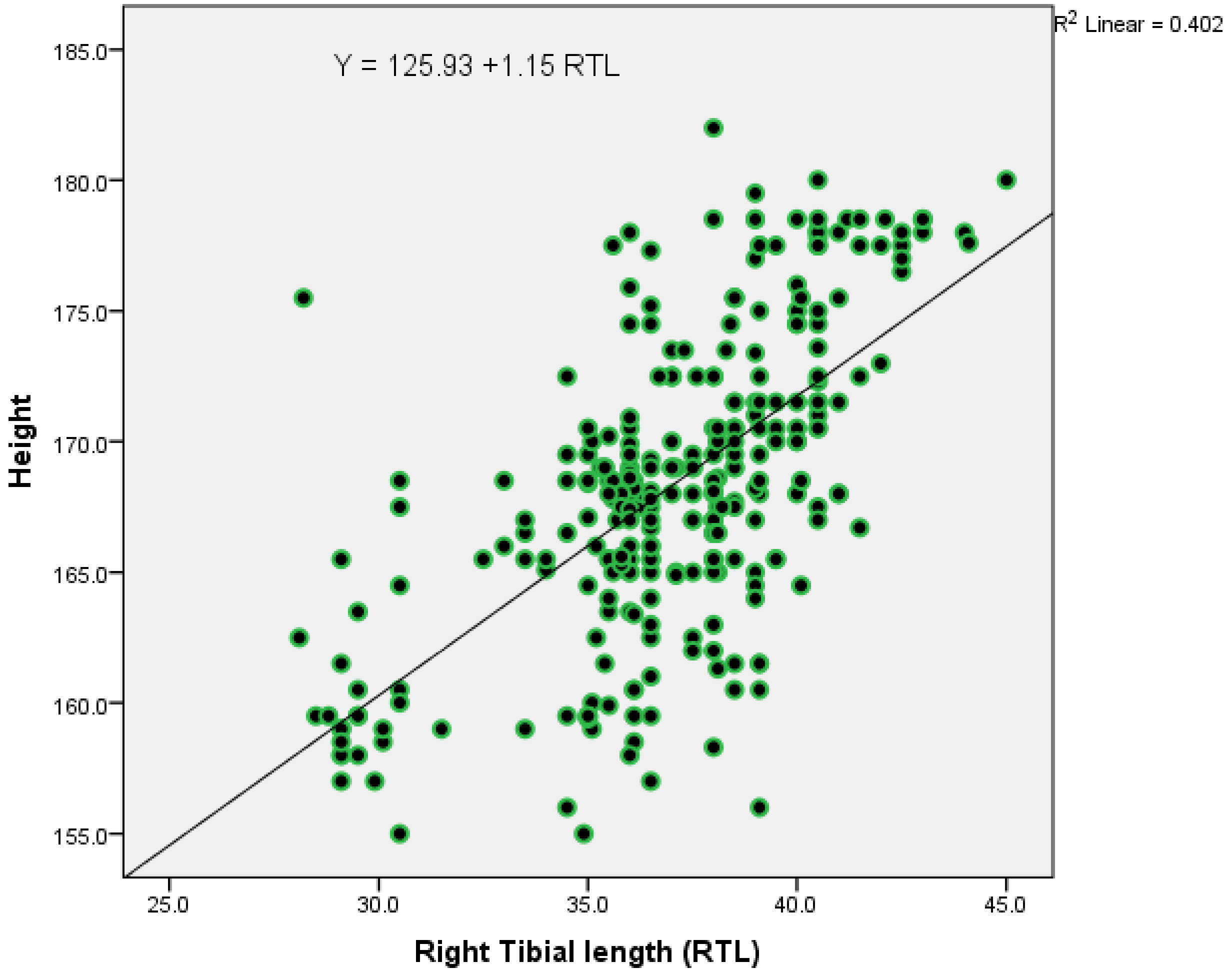


Figure 8: Regression line between height and right tibial length of male participants in Debre Markos University, North West Ethiopia, 2018

The regression line for right tibial length with height was drawn from data analysis of male participants. This graph explains linear relationship between height and right tibial length. It was obvious from the graph that if right tibial length changed, height of respondents also changed or vice versa (Figure 8).

5.6.3. Estimation of stature from each anatomical anthropometric parameters for female participants

Similarly linear regression models were formulated for each anatomical anthropometric measurements to estimate stature for female participants. Table 10 revealed estimation of stature from each anatomical anthropometric measurements of female participants. The SEE was ranged from 3.88 to 3.99 cm in all anatomical anthropometric measurements and R-value also was ranged from 0.122 to 0.259. The R-value was largest in RT tibial length and smallest in LT hand length (Table 10).

Table 10: Estimation of stature from each anatomical anthropometric measurements of female participants in Debre Markos University, North West Ethiopia, 2018

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 + 0.38IAL	.001
RT humeral length	.163	.027	.023	3.97	154.34 +0.34 RHUL	.001
LT humeral length	.159	.025	.022	3.97	154.61 + 0.33 LHUL	.001
RT ulnar length	.147	.022	.018	3.98	155.41 + 0.40 RUL	.001
LT ulnar length	.144	.021	.017	3.98	155.60 +0.39LUL	.001
RT hand length	.125	.016	.012	3.99	146.39 + 1.11 RHL	.001
LT hand length	.122	.015	.011	3.99	146.75 + 1.09 LHL	.001
RT hand breadth	.129	.017	.013	3.99	158.78 + 0.90 RHB	.001
LT hand breadth	.124	.015	.012	3.99	159.22 + 0.84 LHB	.001
RT tibial length	.259	.067	.064	3.88	154.48 + 0.31 RTL	.001
LT tibial length	.258	.066	.063	3.89	154.49 + 0.31 LTL	.001
RT foot length	.185	.034	.031	3.95	154.52 + 0.51 RFL	.001
LT foot length	.186	.035	.031	3.95	154.46 + 0.51 LFL	.001

R = Pearson's correlation, R^2 = coefficient of determination, SEE = standard error of estimate

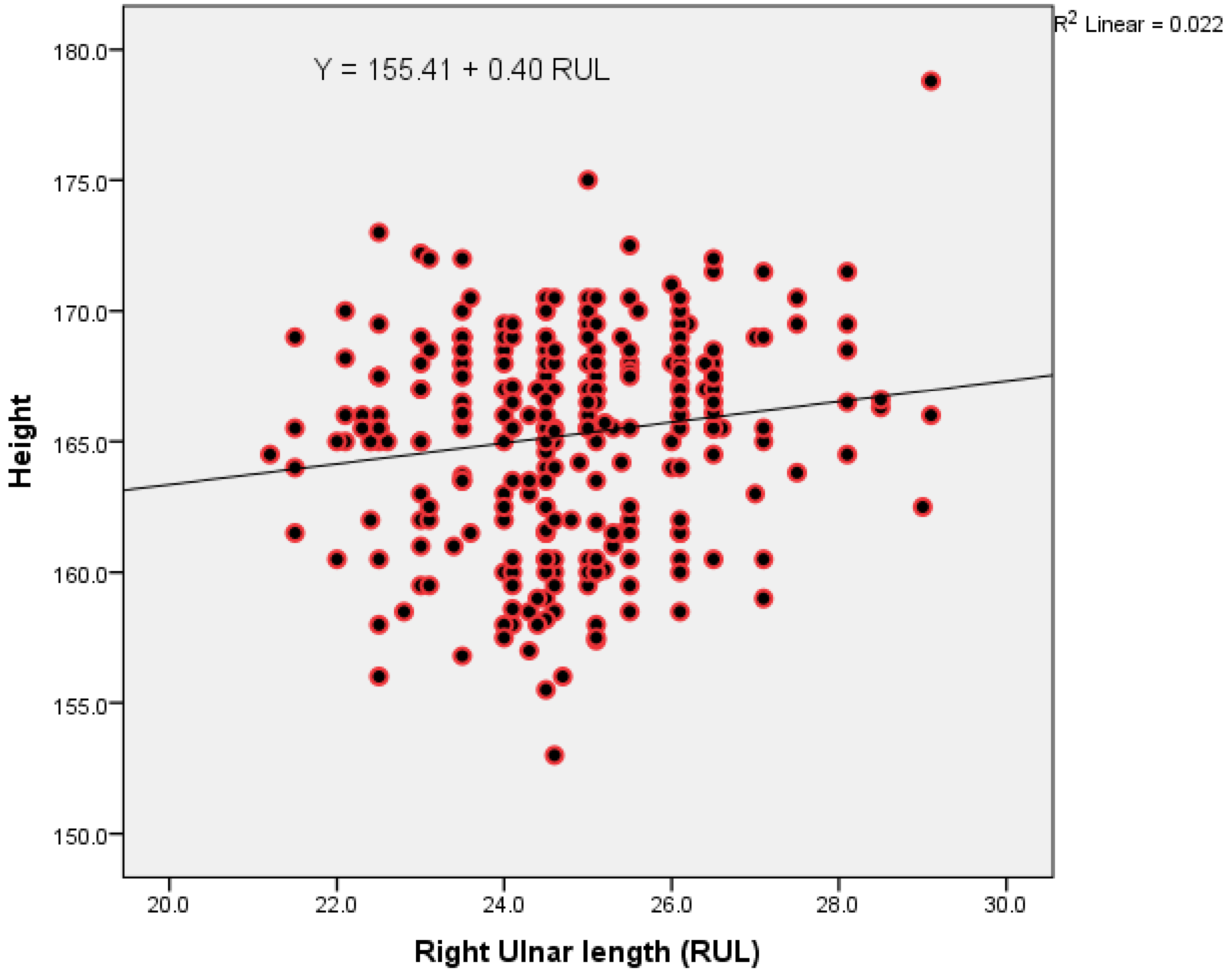


Figure 9: Regression line between height and right ulnar length of female participants in Debre Markos University, North West Ethiopia, 2018

The regression line for right ulnar length with height was drawn from data analysis of female participants. This graph showed the linear relationship between height and right ulnar length. It was obvious from the graph that if right ulnar length increased, height also increased or vice versa. It could be said that height could be predicted from right ulnar length in female participants (Figure 9).

5.6.4. Estimation of stature from combination of bilateral and different anatomical anthropometric parameters for male participants

Multiple linear regression models were formulated by combination of bilateral and different anatomical anthropometric measurements to estimate stature for male participants. Table 11 revealed estimation of stature by combination of bilateral and different anatomical anthropometric measurements of male participants. The largest R-value was 0.666 for combination of right ulnar length (RUL) and right tibial length (RTL). The smallest R-value was 0.363 for combination of left hand length (LHL) and left hand breadth (LHB). The largest SEE was exhibited by combination of left hand length (LHL) and left hand breadth (LHB) which was 5.51. The smallest SEE value was exhibited by combination of right ulnar length (RUL) and right tibial length (RTL) which was 4.41. The largest coefficient of determination (R^2) was 0.444 which is exhibited by combination of RUL and RTL, whereas smallest R^2 value was 0.132 which is exhibited by combination of left hand length (LHL) and left hand breadth (LHB) (Table 11).

Multiple regression equations to estimate stature of male participants from combination of head circumference (HC) and head length (HL), right humeral length (RHuL) and left humeral length (LHuL), right ulnar length (RUL) and left ulnar length (LHL), right tibial length (RTL) and left tibial length (LTL), right foot length (RFL) and right foot breadth (RFB), right ulnar length (RUL) and right tibial length (RTL) are expressed as follows (Table 11):

Stature = 113.98 +0.41 HC +1.00 HL

Stature = 114.02+6.29 RHuL +-4.64 LHuL

Stature = 119.56 + -1.33 RUL +3.22 LUL

Stature = 126.89 + 7.70 RTL+-6.58LTL

Stature = 112.93 + 1.96 RFL + 1.41 RFB

Stature = 110.98 + 0.89 RUL + 0.93 RTL

Table 11: Estimation of stature from combination of Anatomical Anthropometric measurements of male participants in Debre Markos University, North West Ethiopia, 2018

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+ -4.639LHuL	.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+2.33RHL+ 3.51 RHB	.001
LHL-LHB	.363	.132	.125	5.51	1.47	108.94+1.95LHL+3.40 LHB	.001
RTL-LTL	.641	.410	.406	4.54	1.38	126.89+7.70RTL+-6.58 LTL	.001
RFL-RFB	.596	.355	.350	4.75	1.43	112.93+1.96RFL+1.41RFB	.001
LFL-LFB	.595	.354	.349	4.76	1.42	113.23+1.98LFL+1.30LFB	.001
RUL-RTL	.666	.444	.440	4.41	1.25	110.98+0.89RUL+0.93RTL	.001
LUL-LTL	.665	.442	.438	4.42	1.24	110.76+0.90LUL+0.92LTL	.001
RHuL-RHL-RFL	.626	.392	.386	4.62	1.46	84.89+0.82RHuL+1.54RHL +1.35RFL	.001
LHuL-LHL-LFL	.623	.388	.381	4.64	1.45	88.44+0.81LHuL+1.29LHL +1.40LFL	.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

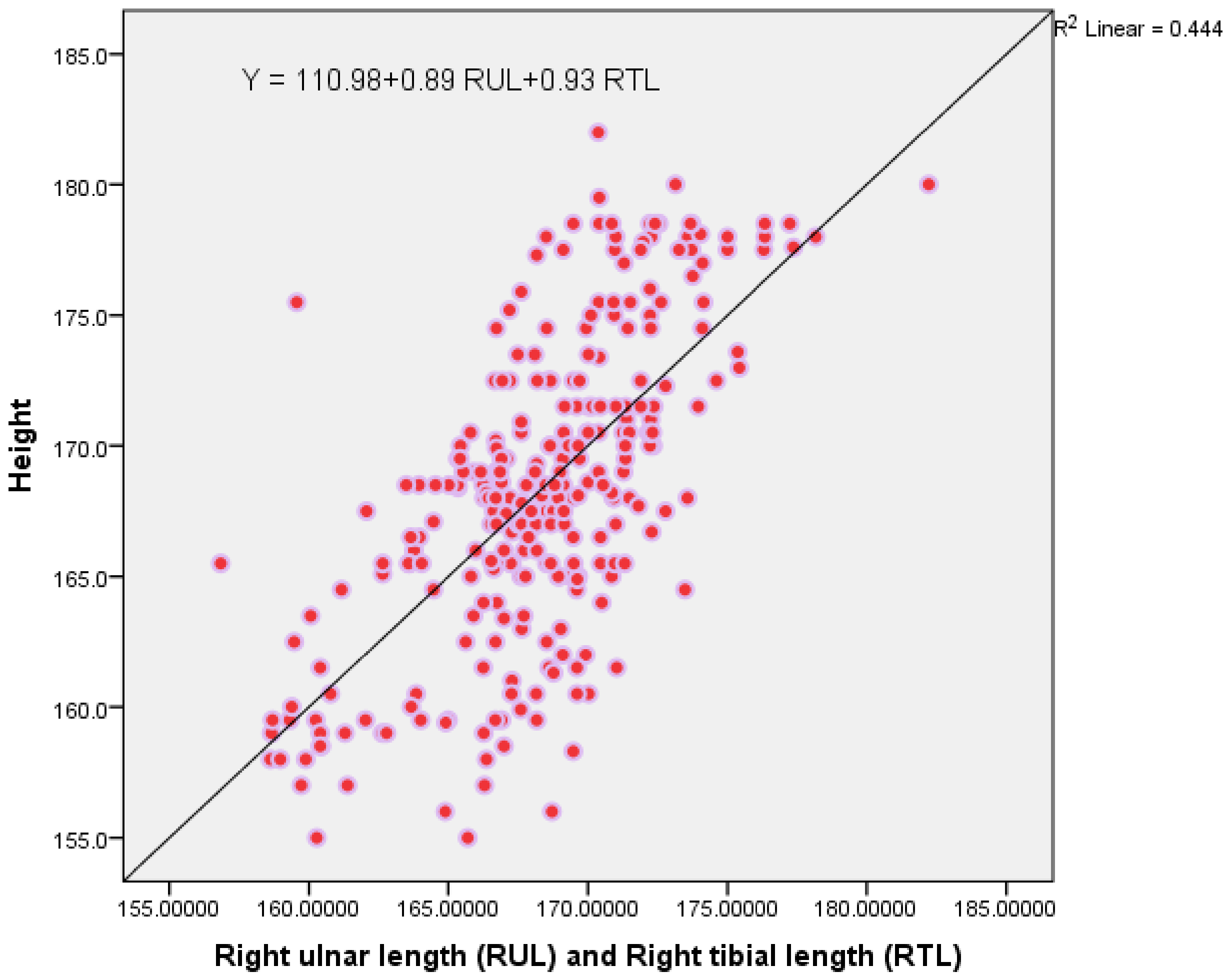


Figure 10: Regression line between height and combination of right ulnar and right tibial lengths of male participants in Debre Markos University, North West Ethiopia, 2018

The regression line for right ulnar length and right tibial length with height was drawn from the combined data analysis of male participants. This graph showed that linear relationship between height and right ulnar length and right tibial length. It was obvious from the graph that if right ulnar length and right tibial length changed, height also changed or vice versa. In simple terms it could be said that height could be predicted from combination of right ulnar length and right tibial length in male participants (Figure 10).

5.6.5. Estimation of stature from combination of bilateral and different anatomical anthropometric parameters for female participants

Multiple linear regression models were formulated by combination of bilateral and different anatomical anthropometric measurements to estimate stature for female participants. Table 12 showed estimation of stature by combination of bilateral and different anatomical anthropometric measurements of female participants. The largest R-value was 0.263 for combination of right tibial length (RTL) and left tibial length (LTL). The smallest R-value was 0.154 for combination of left hand length (LHL) and left hand breadth (LHB) and for combination of right ulnar length (RUL) and left ulnar length (LUL).

The largest SEE was exhibited by combination of right ulnar length (RUL) and left ulnar length (LUL) which was 3.98. The smallest SEE was exhibited by combination of right tibial length (RTL) and left tibial length (LTL) which was 3.89. The largest R^2 value was 0.069 which was exhibited by combination of RTL and LTL whereas smallest R^2 value was 0.024 which was exhibited by combination of left hand length (LHL) and left hand breadth (LHB) and for combination of right ulnar length (RUL) and left ulnar length (LUL) (Table 12).

Multiple regression equations to estimate stature of female participants from combination of head circumference (HC) and head length (HL), right humeral length (RHuL) and left humeral length (LHuL), right ulnar length (RUL) and left ulnar length (LHL), right tibial length (RTL) and left tibial length (LTL), right foot length (RFL) and right foot breadth (RFB), right ulnar length (RUL) and right tibial length (RTL) are expressed as follows (Table 12):

Stature = 151.07 + 0.04 HC +0.38 HL

Stature = 155.11 + 5.47 RHuL+-5.15 LHuL

Stature = 155.37+ 2.90 RUL+-2.50 LUL

Stature = 154.76+2.69 RTL+-2.39 LTL

Stature = 154.92+0.53 RFL+-0.08 RFB

Stature = 154.13+0.02 RUL+0.30 RTL

Table 12: Estimation of stature from combination of anatomical anthropometric measurements of female participants in Debre Markos University, North West Ethiopia, 2018

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

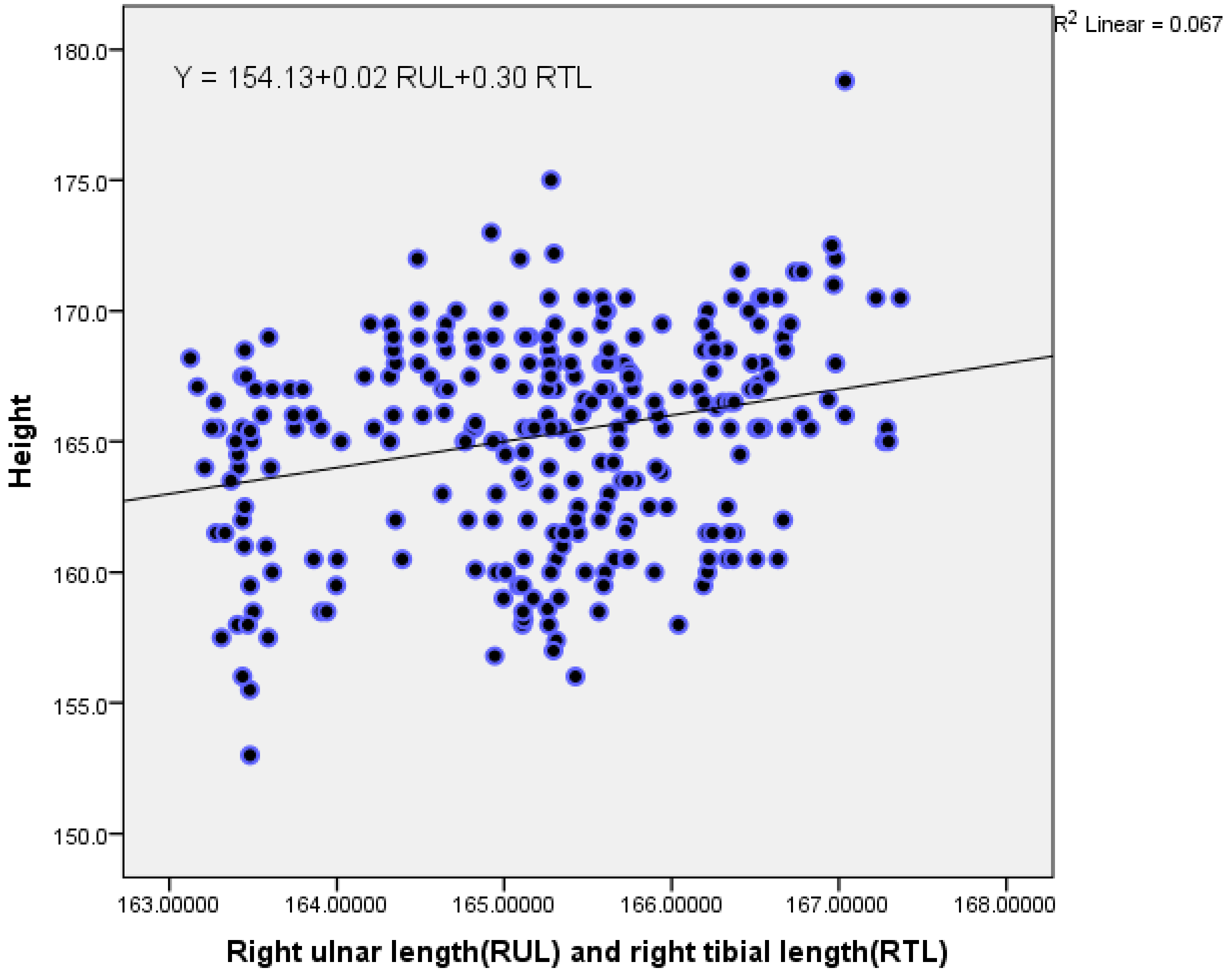


Figure 11: Regression line between height and combination of right ulnar length and right tibial length of female participants in Debre Markos University, North West Ethiopia, 2018

The regression line for right ulnar length and right tibial length with height was drawn from the combined data analysis of female participants. This graph showed linear relationship between height and right ulnar length and right tibial length. It was obvious from the graph that if right ulnar length and right tibial length changed, height also changed or vice versa. In simple terms it could be said that height could be predicted from right ulnar length and right tibial length in female participants (Figure 11).

5.7. Comparison of actual statures and estimated statures

Students unpaired sample t-test was done to compare the existence of mean difference between estimated statures in male and female participants. Independent (unpaired) t-test for comparison of estimated statures for each anatomical anthropometric parameters in both sexes is provided in table 13. For all anatomical anthropometric measurements, there were statistically significant difference ($p<0.05$) between mean values of estimated statures in males and females.

Table 13: Independent t-test for comparison of estimated statures in male and female participants in Debre Markos University, North West Ethiopia, 2018

Parameters (cm)	Male=286 Estimated mean Ht	Female=286 Estimated mean Ht	T-test for equality of means				95% CI	
			T	Sig.	MD	SEE	Lower	Upper
HC	168.355	165.256	21.50	.001	3.10	.14	2.82	3.38
HL	168.368	165.241	20.51	.001	3.13	.15	2.83	3.43
IAL	168.366	165.241	16.65	.001	3.13	.19	2.76	3.49
RHuL	168.367	165.227	16.36	.001	3.14	.19	2.76	3.52
LHuL	168.353	165.252	16.28	.001	3.10	.19	2.73	3.48
RUL	168.361	165.233	17.72	.001	3.13	.18	2.78	3.48
LUL	168.347	165.245	17.52	.001	3.10	.18	2.75	3.45
RHL	168.353	165.234	31.00	.001	3.12	.10	2.92	3.32
LHL	168.360	165.246	34.75	.001	3.11	.09	2.94	3.29
RHB	168.358	165.240	24.86	.001	3.12	.13	2.87	3.37
LHB	168.361	165.238	26.22	.001	3.12	.12	2.89	3.36
RTL	168.346	165.221	13.62	.001	3.13	.23	2.67	3.58
LTL	168.355	165.241	13.61	.001	3.11	.23	2.66	3.56
RFL	168.357	165.238	15.09	.001	3.12	.21	2.71	3.53
LFL	168.359	165.229	15.10	.001	3.13	.21	2.72	3.54

T = t-statistics, MD = mean difference, SEE = standard error of estimate, cm = centimeter, Ht = height, CI = confidence interval, Sig. = level of significance (<0.05)

Students paired sample t-test was done to compare existence of mean difference between actual stature and estimated stature in male participants. Dependent (paired) t-test for comparison of estimated statures and actual statures for each anatomical anthropometric parameters in male participants is provided in table 14. For all anatomical anthropometric measurements, there were statistically insignificant difference ($p>0.05$) between mean values of estimated statures and actual statures in male participants. For instance mean values of actual stature and estimated stature by right ulnar length in males were 168.360±5.8958 cm and 168.3618± 2.92704 cm respectively, and mean height difference at (T = - 0.007, DF = 285) was statistically insignificant ($p>0.05$).

Table 14: Paired sample t-test to see existence of mean difference between actual and estimated stature of male participants in Debre Markos University, North West Ethiopia, 2018

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
RT humeral length	168.36±5.89	168.367±3.17	-.007	.293	-.585	.570	-.025	.980
LT humeral length	168.36±5.89	168.353±3.15	.006	.294	-.573	.586	.022	.982
RT ulnar length	168.36±5.89	168.361±2.92	-.002	.302	-.597	.593	-.007	.995
LT ulnar length	168.36±5.89	168.347±2.93	.012	.302	-.582	.606	.040	.968
RT hand length	168.36±5.89	168.353±1.62	.006	.335	-.652	.666	.020	.984
LT hand length	168.36±5.89	168.360±1.43	-.001	.338	-.665	.665	-.001	1.00
RT hand breadth	168.36±5.89	168.358±2.05	.001	.326	-.642	.644	.003	.998
LT hand breadth	168.36±5.89	168.361±1.95	-.002	.328	-.649	.645	-.006	.995
RT tibial length	168.36±5.89	168.346±3.73	.012	.269	-.5174	.543	.048	.962
LT tibial length	168.36±5.89	168.355±3.72	.004	.270	-.5271	.536	.017	.986
RT foot length	168.36±5.89	168.357±3.41	.002	.284	-.556	.561	.009	.993
LT foot length	168.36±5.89	168.359±3.42	-.001	.283	-.558	.558	.000	1.00
RT foot breadth	168.36±5.89	168.362±1.83	-.003	.331	-.655	.649	-.009	.993
LT foot breadth	168.36±5.89	168.363±1.80	-.003	.331	-.657	.649	-.012	.990

Similarly paired sample t-test was also done to compare existence of mean difference between actual stature and estimated stature in female participants. For all anatomical anthropometric measurements, there were statistically insignificant difference (p>0.05) between mean values of estimated statures and actual statures in female participants. For instance mean values of actual stature and estimated stature by right tibial length were 165.239±4.014 cm and 165.222±1.037cm respectively and mean height difference at (T = 0.075, DF = 285) was statistically insignificant (p>0.05) (Table 15).

Table 15: Paired sample t-test to see existence of mean difference between actual and estimated statures in female participants in Debre Markos University, North West Ethiopia, 2018

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

6. 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) of Debre Markos University. The age group of the students was 18 to 26 years.

In the current 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 on 440 students (258 males and 182 females) in the age group 17 to 25 years (31). 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 compared to this study. 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 disagrees with a study conducted in Nigeria on 500 individuals (261 males and 239 females) in the age group 18 to 30 years (17). In this study was reported that head circumference had 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 current study, head length showed strong correlation with height in males (R = 0.422, P<0.05) than in females (R = 0.168, P<0.05). However a study conducted by Nemade et al (2015) on 300 students (150 males and 150 females) in the age group 18 to 25 years in India revealed that head circumference was strongly correlated with height in males (R = 0.773, P<0.05) than females (R = 0.654, P<0.05) (30). In the current study, head circumference (R = 0.404) was also weakly correlated with height compared to the study findings in India (R =

0.773). This is may be explained by differences in measuring accuracy, precision, sample size or genetics and environmental factors in the two study populations.

In the present study, head length was relatively strongly correlated with stature in males (R = 0.422) than females (R = 0.168). This is in agreement with a study conducted in central India on 470 students (260 males and 210 females) in the age group 18 to 24 years (9). This study also revealed that head length was relatively strongly correlated with stature in males (R = 0.279) than females (R = 0.206).

In the current study, head length was significantly correlated with height in females (R = 0.168, $P<0.05$). This finding contrasts findings of a study conducted in indo-Mauritania population on 150 students (75 males and 75 females) in the age group 20 to 28 years (32). This study showed that head length was not significantly correlated with height in females (R = 0.159, $P>0.05$). This inconsistency between the two studies may be due to differences in measuring instruments, sample size, age group or differences in genetics and environmental factors in two study populations.

In the present study, bi-acromial length was significantly correlated with height in males (R = 0.53, R^2 = 0.281) and in females (R = 0.14, R^2 = 0.20) ($P<0.05$). This is in line with a study carried out in Turkey on 337 volunteers (216 males and 121 females) in the age group 20 to 52 years (36). In this study was also reported that bi-acromial length was significantly correlated with height in males (R = 0.42, R^2 = 0.176) and in females (R = 0.26, R^2 = 0.067) ($P<0.01$). In both studies, bi-acromial length was relatively better predictor of stature in males than females. In the present study, 53% variation of height in males depicted to bi-acromial length. However the study in Turkey, 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, inter-acromial length was strongly correlated with height in males (R = 0.53, $P<0.05$). This finding is inconsistent with findings of a study conducted in India on 300 students (150 males and 150 females) in the age group 22 to 44 years (35). This study revealed that inter-acromial length was weakly correlated with stature in males (R = 0.31) and in females (R = 0.23) ($P<0.01$). This inconsistency may be explained by differences in age group, sample size and measuring instruments in this study and the current study.

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 also $R = 0.163$ for right humeral length and $R = 0.159$ for left humeral length. This is in line with a study conducted in Iran on 100 students (50 males and 50 females) in the age group 19 to 21 years (37). 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 disagrees with findings of the current study in case of females. This may be due to differences in sample size, age group or may be due to variations in genetics and environmental factors in the two study populations.

In the current study, there was statistically significant difference between right and left percutaneous length of humerus in both males and females ($P<0.05$). This finding disagrees with findings of a study conducted in Korea by Lee et al (2014) to estimate stature from upper limb bone length (52). This study revealed that there was no statistically significant difference between right and left upper limb bone length ($P > 0.05$). This lack of agreement may be due to differences in measuring instruments, measurement techniques and measurement errors 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 on 100 students (50 males and 50 females) in the age group 21 to 24 years (40). 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 strongly correlated with height in males than females.

In the current study, right ulnar length was significantly differ from left ulnar length in males and females ($P<0.05$). This is supported by a study conducted by Anitha et al (2009) in south India on 300 male students in the age group 20 to 23 years (15). This study also showed that statistically significant difference was observed between right ulnar length and left ulnar length ($P<0.01$).

In the current study, variation of height due to right ulnar length was 24.6% for males and 2.2 % for females. This finding is relatively less compared to a study conducted in Gulbarga by Anand et al (2016) on 300 students (150 males and 150 females) in the age group 21 to 25 years (41). This study revealed that variation of height in males and females due to right ulnar length was 42.7% and 41.1% respectively. This difference in variation of height due to right ulnar length may be explained by the influence of environment among populations, modernization and social economic development between nations and even among peoples of the same nation.

In the present study, ulnar length was weakly correlated with height in females. The correlation coefficient was R = 0.147 for right ulnar length and R = 0.144 for left ulnar length. However a study conducted in Iran by Ghanbari et al (2016) on 50 female students in the age group 19 to 24 years revealed that ulnar length was strongly correlated with height (16). The correlation coefficient was 0.753 for right ulnar length and 0.731 for left ulnar length. This difference in strength of correlation of ulnar length with height may be attributed to differences in sample size and age group in the two study populations.

In the present study, hand length was significantly correlated with height in males (R = 0.276, R = 0.243) and in females (R = 0.125, R = 0.122) for right and left hand lengths respectively ($P<0.05$). This finding is supported by a study conducted in North India by Agrawal et al (2013) on 100 males and 100 females in the age group 18 to 25 years (11). In their study, there was a significant correlation between hand length and height, R = 0.608 for males and R = 0.658 for females ($P<0.05$). However the difference in strength of association may be explained by differences in sample size, genetics and environmental factors such as nutrition and climate in the two study populations.

In the current study, hand breadth had 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 disagrees with findings of a study conducted in India on 268 adults (158 males and 110 females) in the age group 20 to 39 years (50). 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 is may be due to differences in age group, sample size, measuring instruments or genetics and environmental factors in this study and the current study.

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 were 0.634 and 0.632 for right and left tibial lengths respectively. The correlation coefficient (R) between height and tibial length in females were also 0.259 and 0.258 for right and left tibial lengths respectively. This finding is supported by a study conducted on 540 students (270 males and 270 females) in the age group 18 to 21 years in Madhya Pradesh (4). In this study was also reported that the correlation coefficients (R) between height and tibial lengths in males were 0.417 and 0.442 for right and left tibial lengths respectively; and in females were 0.570 and 0.604 for right and left tibial lengths respectively.

A similar study was also carried out by Mehta et al (2015) on 80 adults (40 males and 40 females) in the age group 18 to 30 years in central India (45). This study concluded that there was a strong correlation between height and tibial length in both sexes with R = 0.886 and R = 0.864 for right tibial length and left tibial length respectively. This study findings agree with findings of the current study in which tibial length was strongly correlated with height in males (R = 0.634, R = 0.632) and in females (R = 0.259, R = 0.258) for right and left tibial lengths respectively. However there was a difference in strength of association between tibial length and height in this study and the current study. This is may be due to differences in sample size, measuring instruments and age group in the two studies.

In the current study, the variation of height depicted due to tibial length was 40.2% in males (R = 0.634, $R^2 = 0.402$) and 6.7% in females (R = 0.259, $R^2 = 0.067$). However a study conducted by Khatun et al (2016) on 400 students (200 males and 200 females) in the age group 17 to 24 years in Indian (1) was reported that height variation due to tibial length was 74 % in males (R = 0.86, $R^2 = 0.74$) and 72% in females (R = 0.85, $R^2 = 0.72$). This variation difference in height due to tibial length may be explained by differences in genetic and environmental factors like nutrition and climate in the two study populations.

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 on 640 students (343 males and 297 females) in the age group 18 to 23 years (47). 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; and in females 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. This is may be due to differences in measuring instruments, measuring error or due to genetic and environmental factors like nutrition and climate in the two study populations.

In the current study, statistically significant difference was observed between right and left foot lengths in males and females (P<0.05). This agrees with a study conducted in Maharashtra on 200 students (100 males and 100 females) in the age group 18 to 23 years (53). In this study was reported that significant bilateral difference was observed between right and left foot length in males and females (P<0.05). The correlation coefficient between height and foot length was also statistically significant in males and females (P<0.05).

A similar study was carried out in West Bengal, India by Datta Banik S (2016) on 268 adults (158 males and 110 females) in the age group 20 to 39 years (44). His study revealed that significant correlation of foot length and breadth with height in males (R = 0.53, R =0.40) and (R = 0.53, R = 0.43) for right foot length and breadth and left foot length and breadth respectively; and in females (R = 0.33, R =0.41) and (R = 0.37, R = 0.34) for right foot length and breadth and left foot length and breadth respectively (P<0.05). This is in agreement with findings of the present study where foot length and breadth in males and only foot length in females were significantly correlated with height. However in the current study, foot breadth was insignificantly correlated with height in females (P>0.05). This is may be due to differences in sample size, age group and study design (institution based and community based) in the two study populations.

In the present study, multiple linear regression models were relatively better predictor of stature than simple linear regression models in both males and females. This finding agrees with a study conducted by Khanapurkar et al (2012) on 1000 students (536 males and 464 females) in the age group 19 to 22 years in Maharashtra concluded that multiple linear regression equations were better predictor of stature than simple linear regression equations (12).

In the present study, gender differences in 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 that of females ($P<0.05$). This finding is similar to findings of studies conducted by Nemade et al (2015), Anam et al (2014) and Khanapurkar et al (2012) (12, 30, 34).

7. CONCLUSION

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 were significantly correlated with height in both sexes ($P<0.05$). However, foot breadth was insignificantly correlated with height only in females ($P>0.05$).

Out of all 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 that of females and this gender differences in mean of all anatomical anthropometric parameters were statistically significant ($P< 0.05$).

Linear regression models were formulated from each anatomical anthropometric parameters to predict height of an individual, 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.

8. LIMITATIONS OF THE STUDY

- There is very limited published data in Ethiopia on this area: and therefore no literature was available to compare findings of the present study at national level.
- Refusal of some students to participate in the study due to physical rigours of taking different anatomical anthropometric measurements.
- Because of geographical variations in physical or anatomical dimensions of different population groups, linear regression models developed in the current study were specific for only this population in which samples were withdrawn.

9. RECOMMENDATIONS

- Large scale and multi center similar researches should be conducted in other universities such as Addis Ababa University and metropolitan Universities, which are expected to represent participants from different geographical areas, to develop nationwide guide line which can be easily used throughout the country.
- It would be ideal to carried out a similar study in short and tall groups of individuals in the community because there is indigenously short and indigenously tall communities.
- Further studies should be conducted to investigate reasons for bilateral asymmetry of anatomical anthropometric parameters studied as there was a difference in size between right and left.

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ANNEX 1

Informed Consent Form

My name is……………………………..and I am post graduate student in human Anatomy department, college of health sciences, Addis Ababa University and now I am conducting research on estimation of stature from head circumference, head length, inter acromial length, humeral length, ulnar length, hand length, hand breadth, tibial length, foot length and foot breadth. The purpose of this thesis is to assess the relation between stature and these anthropometric parameters. Participants don't face any harm and whatever information you provide will be kept confidentially by using only code numbers and will not be shared to any other person. I hope you may participate in the study since your participation is very important to generate new knowledge. If you agree I will measure about 5-10 minutes of the above parameters and I allow you to fill the following short questions. It is based on respondent's full consent so I kindly request you to give the correct answer.

Thank you for your cooperation.

ANNEX 2

Questionnaire

Part I. Socio-demographic Variables

Question No.	Questions	Alternatives
101	Sex	1. Male 2. Female
102	How old are you in completed years?	……………Years
103	Residence	1. Urban area 2. Rural area
104	From which region you spent most of your age?	1. Addis Ababa 2. SNN 3. Amhara 4. Somali 5. Oromiya 6. B/gumeze 7. Tigray 8. Gambella 9. Afar 10. Harari
105	To which ethnic group do you belong?	1. Amhara 3. Oromo 2. Tigray 5. Somalia 4. SNN 6. other--------------

Part II. Anthropometric Variables

Instruction: All measurements were recorded to 1 decimal place.

Question No.	Variables	Equipment	Scale
201	Stature/Height	Stadiometer	Centimeter
202	Head circumference	Non-elastic tape meter	Centimeter
203	Head length	Non-elastic tape meter	Centimeter
204	Inter-acromial length	Non-elastic tape meter	Centimeter
205	Right humeral length	Non-elastic tape meter	Centimeter
206	Left humeral length	Non-elastic tape meter	Centimeter
207	Right ulnar length	Non-elastic tape meter	Centimeter
208	Left ulnar length	Non-elastic tape meter	Centimeter
209	Right hand length	Sliding caliper	Centimeter
210	Left hand length	Sliding caliper	Centimeter
211	Right hand breadth	Sliding caliper	Centimeter
212	Left hand breadth	Sliding caliper	Centimeter
213	Right tibial length	Non-elastic tape meter	Centimeter
214	Left tibial length	Non-elastic tape meter	Centimeter
215	Right foot length	Non-elastic tape meter	Centimeter
216	Left foot length	Non-elastic tape meter	Centimeter
217	Right foot breadth	Non-elastic tape meter	Centimeter
218	Left foot breadth	Non-elastic tape meter	Centimeter
219	Weight	Mechanical balance	kilo gram

ANNEX 3

Figures that show height, weight and anatomical anthropometric measurements

Figure 12: Measuring height of male (right) and female (left) respondents

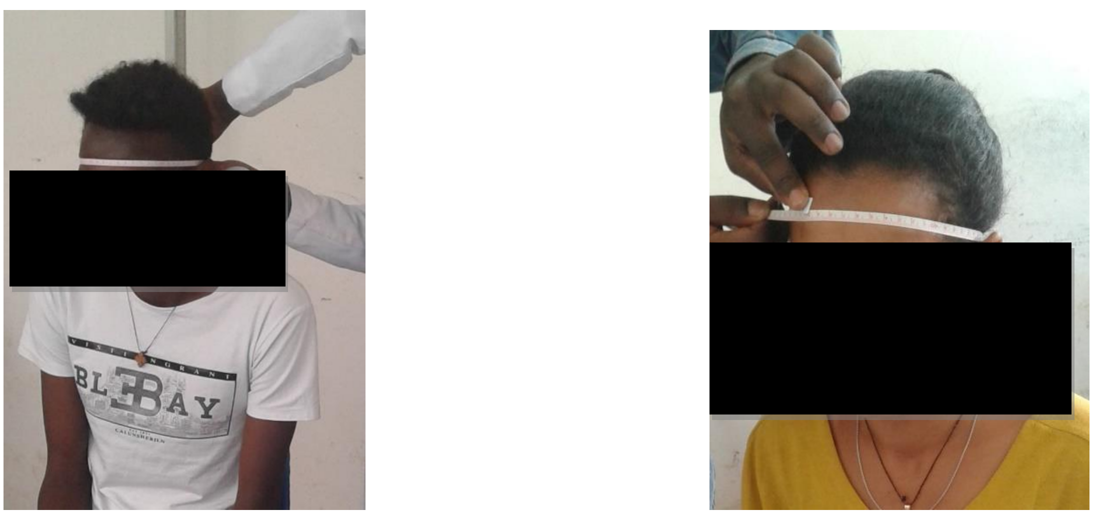

Figure 13: Measuring head circumference of male (right) and female (left) respondents

Figure 14: Measuring head length of male (right) and female (left) respondents

Figure 15: Measuring inter-acromial length of male (right) and female (left) respondents

Figure 16: Measuring humeral length of male (right) and female (left) respondents

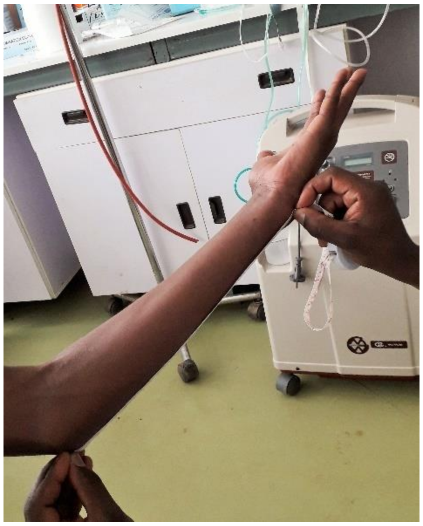

Figure 17: Measuring ulnar length of male (right) and female (left) respondents

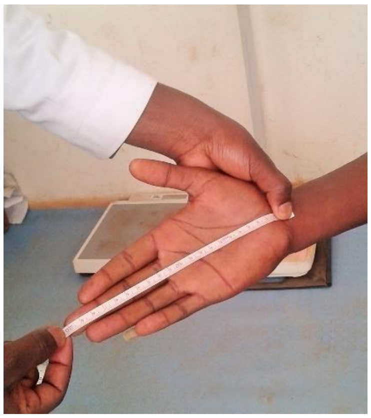

Figure 18: Measuring hand length of male (right) and female (left) respondents


Figure 19: Measuring hand breadth of male (right) and female (left) respondents


Figure 20: Measuring tibial length of male (right) and female (left) respondents

Figure 21: Measuring foot length of male (right) and female (left) respondents

Figure 22: Measuring foot breadth of male (right) and female (left) respondents