
**ADDIS ABABA UNIVERSITY**

**COLLEGE OF HEALTH SCIENCE, SCHOOL OF MEDICINE**

**DEPARTEMENT OF MEDICAL ANATOMY**

# Estimation of Stature from Arm Span, Arm length and Tibial Length among Adolescents of Age 15-18 in Addis Ababa, Ethiopia

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**A THESIS SUBMITTED TO THE DEPARTMENT OF MEDICAL ANATOMY, SCHOOL OF MEDICINE, COLLEGE OF HEALTH SCIENCES, AND ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR MASTER OF SCIENCE DEGREE IN ANATOMY.**

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**Addis Ababa, Ethiopia**

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College of Health Sciences, School of Medicine

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# Estimation of Stature from Arm Span, Arm length and Tibial Length among Adolescents of Age 15-18 in Addis Ababa, Ethiopia

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## APPROVED BY THE BOARD OF EXAMINERS

This thesis, by Bereket Sisay is accepted by the board of examiners as a partial fulfilling for the degree of masters in Anatomy.

Title: Estimation of Stature from Arm Span, Arm length and Tibial Length among Adolescents of Age 15-18 in Addis Ababa, Ethiopia

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# ABBREVIATION AND ACRONYMS

| | |
|---|---|
| AACAEB | Addis Ababa City Administration Education Bureau |
| AAU | Addis Ababa University |
| AS | Arm span |
| CI | Confidence Interval |
| DNA | Dioxyribonucleic acid |
| ISAK | Interinational society for advancement of kinanthropometry |
| LAL | Left arm length |
| LTL | Left tibial length |
| MF | Multiplication factor |
| PCTL | Peri cutanues tibial length |
| RAL | Right arm length |
| RTL | Right tibial length |
| SEE | Standard Error of Estimate |
| SD | Standard Deviation |
| SPSS | Statistical Package for Social Science |

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# Abstract

**Background**: Stature/height is one of the most important variables used for identification of a person. Knowing the relationship between stature and different anatomical anthropometric parameters will aid forensic scientists, Anatomists and Medical scientists to estimate standing height from mutilated remains of body parts in forensic investigation. And it's a necessity when measuring height is unenviable due to certain medical conditions and in field studies. There are multitude of studies done in different areas of the world on prediction of stature from arm span, arm length and tibial length in adults, but it's rarely tried in adolescents and the situation is worse in our country. As my search has shown this study is the first of its kinds in addressing the issue in the area.

**Methods**: A high school based cross-sectional study was carried out among 416 High school students in Addis Ababa from May to June 2019. Stratified multi-stage sampling techniques were used to select the study participants. Anthropometric measurement including weight, height, arm span, arm length and tibial length was measured. Data entry was done by Epi-Data a version 4.4.3.1 and data analysis was carried out by SPSS for windows version 23. And regression models and multiplication factors were generated for estimation of height from anthropometric parameters.

**Result:** Out of the total participants 51.4% were females and 48.6% were males. The mean height of study participants was 164.36 ± 8.89 cm for males and 155.75 ± 5.86 for females. The correlation coefficients (R) of anatomical anthropometric measurements with height were: arm span (males R = 0.843, females R = 0.708), right arm length (males R = 0.806, females R = 0.635), left arm length (males R =0.813, females R = 0.636), right tibial length (males R = 0.738, females R = 0.611), and left tibial length (males R = 0.744, females R = 0.599).

**Conclusion:** The findings connotes that in circumstances where height cannot be measured, stature predicted from arm span, arm length, and tibial length is a valid indicator of height. Arm span was appeared to be the best predictor of stature.

**Keywords**: stature, arm span, arm length, tibial length, estimation

# 1. INTRODUCTION

## 1.1 Background

Stature or standing height is a measurement taken from the heel to the vertex of the head while the person is in erect position(Lohman et al., 2008). In numerous scientific studies it's well known that the measurement of height is important in many fields of studies. It is an essential measure of body size and help for assessing the nutritional status of an individual (Datta Banik et al., 2011).

Anthropometry, which deals with describing human form in numbers, has been widely used in forensic investigations and in many clinical circumstances. Sex, age, stature and race will help to nail down the pool of victims match forensic investigations. From all of the above variables stature is the most vital tool for personal identification incase when only remains of a human body found.(Patel et al., 2012).

Stature is also a vital tool for assessing growth, nutritional status, basal metabolic rate, creatine to height ratio, pulmonary function, body surface area for medication dosage, glomerular filtration, and for other purposes in childhood and adolescence (Lohman et al., 2008).

Furthermore, issues and troubles in estimation of height can be looked in field studies compared with clinical settings because of none convenience and availability particular instruments utilized for estimation of stature. Therefore, alternative measures of height that can be acquired by simple and portable instruments are required.(Muncie et al.,2001)

There are two scientific methods used for predicting standing height from segmental length of an individual. The mathematical method is a method for predicting the stature by formulating mathematical regression formulas from the measurements of many bones of the body. The main principle of Trotter and Gleser's prediction model is the comparison of the measured part of the skeletal remain to the equivalent in living person or cadavers(Trotter et al., 1952).

The Fully's technique otherwise called anatomical method, is clarified by numerous researchers as the most precise stature estimation strategy, profiting by the incorporation of all the skeletal components of a person that contribute straightforwardly to standing height(Raxter et al., 2006). Measurements collected from these skeletal elements are added to get the total skeletal height plus a soft tissue correction factor is summed to generate an estimate of living stature(Fully et al., 1956).

The anatomical method cannot be used commonly by forensic anthropologists in the estimation of height due to lack of the complete skeletal elements of victims which is always the case in mass disasters. It is then obvious why forensic anthropologists most of the time use mathematical method for estimating height from the few fragmented part of the body (Lukpata et al., 2015).

## 1.2 Statement of the problem

Forensic cases based on human body remains of an individual often include prediction of stature; the predicted stature is then compared with both reported and recorded stature of missing individuals. This potentially useful characteristic is generally omitted for skeletal remains of a child, however, In case of child skeletal remains, long bones are used to estimate age rather than stature(Smith et al., 2007).

This condition is understandable. For a kid, age is a fundamental distinguishing factor than tallness. At times, for example, those including mixing together of remains or casualties of war or mass calamities, stature estimation were significant. For example, in the Oklahoma case with two missing young girls of comparative age where detailed and stature estimation dependent on a femoral length end up being basic in the last distinguishing proof of one of the young girls(Snow et al., 2003).

As of late, establishing the personality of a person from remains of body part has become a significant need because of huge frequency of natural and manmade debacles like quakes, waves, floods, bomb impacts, mass mishaps, building breakdown, wars, and plane accidents which cause mass fatalities. For example WHO report demonstrates that every year more than 1.24 million individuals bite the dust with just car accidents and 90% of death is from low and middle income nations and kids and teenagers take the most weight of the casualty(Nihal et al., 2014).

As indicated by WHO yearly catastrophic event measurable audit of 2015, in average 380 cataclysmic events happened every year around the world and cause death of 199.2 million individuals from 2005 to 2014 overall like manmade disasters kids and juvenile take the most weight of death from these natural disasters.(Nihal et al., 2014).When such debacles occurred only remains of body parts were found, this cause difficulty to build complete biological profile of the victims, so estimation of height from various body part may assume fundamental role in criminological anthropological field to fill the gap of biological profile for recognition of person after death(Wakode et al., 2015).

Last year similar identification problem was encountered in deadly plane crash in Bishoftu, Ethiopia. The plane with model of Boeing 737 max 8, with flight number of ET 302 were heading to Nairobi the capital of Kenya from Bole international airport, Addis Ababa. There were 157 passengers and crew members in the plane from more than 35 nations and with different age groups. No survivors were found and only the fragmented and mutilated body parts were found and used for identification of the victims.

Even if standing height plays a big role in personal recognition of a person in case of medico legitimate cases and in many clinical situations, there are numerous conditions which frustrate the immediate estimation of standing stature like loss of motion, fractures, amputations, scoliosis and pain, in these conditions segmental length of the body is used to predict height.(Quanjer et al., 2014).

Age, gender, ethnicity, climatic condition, nutrition, hereditary components are accepted to be the fundamental determinant variables of the physical appearance of a person. Therefore, most regression models generated are meant to be specific for a particular region. Consequently, equations inferred around the world can be utilized uniquely in that specific area of study and for that specific age bunch in which the investigation was done.(Lohman et al., 2008) It is, therefore, mandatory to derive regression models which are age group, gender, ethnic, and geographic area specific. As my search has shown, there is no study done in Ethiopia in adolescents below 18 years of age on estimating stature from different anthropometric parameters, so this study is the first of its kind in the region to address this issue.

## 1.3 Significance of the study

Understanding the connection between stature and diverse anthropometric parameters will support forensic researchers, Anatomists and Medical scientists to predict stature from dismantled body parts in criminological assessments which will help in identification of person.

In addition, the findings of this study will be used as an alternative measure of standing height of adolescents in a number of clinical conditions which hinder the measurement of height like chronically ill adolescent who cannot stand from bed and for adolescents with limb deformities.

Also, the discoveries of this study will be utilized as an elective measure of standing stature of young people in various clinical conditions which impede the measurement of height like incessantly sick adolescents who can't stand from bed and for teenagers with spinal and limb deformities.

There are several research completed in many areas of the world on estimation of stature from arm span, arm length and tibial length in adults, but it’s hardly ever tried in youngsters and the scenario is worse in our country. And finding of this study is the first of its sorts in representing children of age beneath 18.

Besides, the finding of this study will help a great deal by giving alternative measure of height in field contemplates where direct measurement of stature becomes troublesome due to none transportability and availability specific instruments utilized for height measurement.

The discoveries of this study will likewise be utilized as a source of perspective information for further detailed studies on the issue.

# 2. LITERATURE REVIEW

Foundation of personality of obscure human remains is a difficult errand in medico-legal cases, particularly when the remaining parts are incomplete or dismantled. In this study published literatures on height, methods for estimation of height, factors affecting height, sexual dimorphism in height estimation and correlation of different anthropometric parameters and stature are reviewed.

## 2.1 Methods for estimation of stature

### *2.1.1 The anatomical method (Fully's method)*

The Fully's method for stature estimation was found to be the most accurate stature estimation method, benefiting from the inclusion of all the skeletal elements that contribute directly to physical appearance of an individual.( Ousley et al., 1995).

The greatest disadvantage of Fully's anatomical equation for stature estimation is non-accessibility of the total skeletal elements from the unfortunate casualty which is consistently the situation in mass debacles. It is then obvious why forensic anthropologists often use mathematical linear regression method, which can be applicable in circumstances where only remains of body parts were found.(Lukpata et al., 2015).

### *2.1.2 The mathematical method*

Nowadays the mathematical method of stature estimation becomes virally used. Its stature estimation method by formulating a mathematical regression coefficient obtained from the measurements of segmental length of the body.

## 2.2 Factors affecting stature

In recent years there are five well known determining factors affecting the physical appearance of an individual. These five factors are genetics, climate, altitude, pathology, and nutritional status (Beall et al., 2006, Vercellotti et al., 2014,Wood et al., 2014).

### 2.2.1 Genetics and Stature

It is ordinarily realized that hereditary factors represents a huge part of grown-up stature. Albeit hereditary factors can represent up to 90% of stature variety in people, hereditary investigations have discovered that in excess of 9,500 Single Nucleotide Polymorphisms (SNPs) represent just 29% of stature decent variety in a population. This shows varieties in the genome control a little part of the decent variety saw in physical appearance among people. (Yang et al., 2010,Wood et al., 2014).

### 2.2.2 Climate and stature

In many studies done on skeletal morphology and evolutionary adaptation, climate is explained as the relative mean ambient temperature for a geographic region(Serrat et al., 2008,Wells et al., 2012,). Starting from the mid-nineteenth century, the impact of climatic conditions on body extents and appendage morphology has been depicted by numerous researchers. The first of these depictions is ascribed to Carl Bergmann and called Bergmann's rule. It expresses that population found in colder climatic condition will have bigger weight than those in hotter climatic condition (Bergmann, 1847). Joel Allen expanded the explanation of this rule by adding that difference occurs in the ratio between volume and surface area of the body (Allen, 1877).

As surface area-to-volume proportion increase, heat is more effectively exchanged between the person and the environment, and this condition result in loss heat caught inside the body. The inverse is genuine for a lower surface area-to-volume proportion; this causes a decreased misfortune of inside warm in colder situations. In order for the body to adjust and change the surface area by keeping up the volume, the length limbs must increase resulting in taller and more slender people in hotter natural condition and shorter and more robust people in colder natural conditions(Wells et al., 2012). According to (Serrat et al., 2008) cold environmental conditions influence growth of an person by decreasing the multiplication of chondrocytes. Chondrocytes control the deposition of endochondral bone by influencing endochondral solidification of bone, but not intramembranous bone, in this way it will affect diaphyses of long bones.

### *2.2.3 Effects of Altitude on stature*

Factor affecting individuals at high altitude (environments above 2,500 meters above sea level) is hypobaric hypoxia (reduced oxygen in the air due to reduced atmospheric pressure)(Beall et al,, 2006).Residence at this high altitude have developed biological responses to the environment that allow them to survive with limited oxygen(Beall et al., 2006). Numerous researches done have showed that non-residents in these geographic regions are more severely affected by the hypobaric hypoxia than lifelong residents, and this diminishing of the negative effects during adulthood have been explained as adaptations to the condition(Bailey et al., 2007,Bogin et al., 2007).Reduced oxygen level and the energy requirements of high-altitude environments affect the growth of individuals in uterus as well as throughout the whole childhood(Bailey et al., 2007). Specifically, stunted growth most commonly appears in the lower limbs and is more pronounced in the tibia. Compared with relative new residents, lifelong residents of high-altitude regions present fewer effects of hypobaric hypoxia(Bailey et al., 2007).

### *2.2.4 Effect of pathology on stature*

Congenital medical conditions, those affecting skeletal size and shape since birth, are clearly discernible in the long bones, and the two most common conditions that stunt growth and result in short stature are achondroplasia and pituitary dwarfism. Achondroplasia is a specific form of dysplasia that leads to abnormal endochondral bone ossification but normal intramembranous bone growth(Rodríguez et al., 2012, Waters-rist et al., 2013). Diagnostic postcranial traits include disproportionate length of bones most pronounced in longer bone of the individuals commonly the femur and humerus and normal cortical thicknesses and diaphyseal diameters with disproportionately wide epiphyses and metaphysis(Rodríguez et al., 2012,Waters-rist et al., 2013).

Pituitary dwarfism is the result of a deficiency in a growth hormone leading to dwarfism. The skeleton is characterized by thin cortical bone, sparse trabeculae, and a thin bony layer closing the metaphyseal surface indicating stunted growth of bone and leading to non-union of the epiphyses until late adulthood stage of life(Aristova et al., 2006).

#### *2.2.5 Nutrition Deficiency and stature*

Pathological conditions influencing stature may likewise be identified with nutritional inadequacy. The commonest among these conditions because of nutritional deficiency are rickets and osteomalacia. It's hard to separate rickets and osteomalacia however they enormously influence the morphology of long bone during growth(Ortner et al., 1998).They are linked with a vitamin D deficiency. While vitamin D can be orchestrated by the body through exposure to the daylight or procured through eating routine, areas with colder climatic condition and those with less exposure to sunlight due to high cloud cover and general nutritional deficiency conceivably lead to the sign of these pathological conditions(Hoffman et al., 2012).

Most pathologic conditions that influence morphology of bone seriously can be distinguished through straightforward perceptions; be that as it may, not every single obsessive condition can be handily analyzed and some may have been crushed when the patient dies. Less serious variety in nutritional status, explicitly zinc and iron defficiences, will prompt hindered development in stature(Black et al., 2008).

## 2.3 Sexual dimorphism in stature

Females are on average shorter than guys in each known populace. This distinction in stature between genders is called sexual dimorphism of stature and exists in each general public. A few populaces have more noteworthy variety in normal statures among male and female than do others. There has been no surely known logical accord with respect to why this happens. Stature is hereditarily characterized quality, as is sexual dimorphism in a populace(Gray et al., 2001)..

The cause of the stature distinction among guys and females is most ordinarily ascribed to result from hormonal and sex chromosome composition. Sex hormones, for example, estrogen and testosterone are profoundly applicable in closure of growth plates in the long bones and they additionally influence the secretion of other growth related hormones, for example, growth hormone and insulin-like growth factor, along these lines it is sensible to estimate that the differential sex steroid examples may contribute some part in sex distinction in stature(Giles et al., 1999).

## 2.4 Effect of aging on height

It is commonly acknowledged that stature decays with age after adult hood. As indicated by Giles and Hutchinson, it is a sensible presumption that populations, especially those in the United States, were start to diminish in height after the age of 45. This insignificant lessening in standing stature starts for guys at about 1 mm/year, and about 1.25 mm/year in females(Giles et al., 1991).

Regression equations used for stature prediction in use today require modification to account for stature loss due to aging in adult populations. Galloway (1988) found that height diminishes on normal by 0.16cm every year after age 45. She proposes that 0.16cm (age less 45) ought to be incorporated in to stature estimation condition while examining more established people over 45 years of age(Galloway et al., 2006).

## 2.5 Correlation of different anthropometric parameters with stature

### *2.5.1 Correlation of arm span with stature*

The aftereffect of study done on a sum of 5358 primary and secondary school students (2737 young girls, 2621 young boys) in the age range of 6–17 years in Turkey indicated linear regression model to predict height from arm span were Height = 13.4396+0.9037(arm span); with Pearson correlation coefficient of 0.95 for boys and, Height = 16.4181+0.8865 (arm span); Pearson correlation coefficient of 0.93 for girls. The correlation between arm span and height profoundly noteworthy with Pearson correlation coefficient 0.83 and *p- value of* 0.001 (Mazicioglu et al., 2009).

Based on a study carried out on 4715 Southern Chinese youngsters of age 6-17 in 2015, sitting height, forearm length, upper arm length, arm span and lower leg length were used to predict standing height of youngsters and the finding indicated that all the parameters are highly correlated with stature with *r value* >0.9 and *P- value* < 0.05 and arm span were the most dependable estimate of the height.(Zhu et al., 2015).

As per to a study done in Jimma, South west Ethiopia, on 660 study participants of age 18-40 a multivariable linear regression model using age and sex as a confounding variables showed that arm span (β=0.63, p- value <0.001, ($R^2$=87%), half arm span (β=1.05, p-value <0.001, ($R^2$=83%), and knee height (β=1.62, p-value <0.001, ($R^2$=84%) predicted stature dependably. And Based on the result of coefficient of determination arm span was found to be good estimator of height compared to other anthropometric parameters(Digssie et al., 2018).

A study done in Malawi among 626 participants of age 6-15 demonstrated that the mean difference between the two anthropometric parameters (stature and arm span) for boys was 5.45 +/- 4.21 cm (t = 3.556, p < 0.001) and for girls was 4.94 +/- 4.96 cm (t = 3.542, p < 0.001). Furthermore the computed Pearson correlation coefficient between arm span and standing height measurements for boys was 0.983 and for girls was 0.986.(Zverev et al., 2005).

According to the result of school based cross sectional study done in Bengale, Hindu on a sum of 240 children of aged 3-11 years, stature was found to be significantly correlated with age with Pearson correlation coefficient of 0.886 and p- value of <0.01, arm span with Pearson correlation coefficient of 0.978 and p- value of <0.01 and other parameters like arm length and tibial length among boys. Similarly, it was significantly correlated with age with Pearson correlation coefficient of 0.829 and p-value of <0.01and arm span with Pearson correlation coefficient of 0.972 p- value of <0.01among girls.(Dorjee et al., 2016).

The aftereffect of an investigation carried out on 1769 male and female youngsters aged 8-18 in Limpopo province, South Africa, the result indicated higher mean value of height than arm span, with d/ce ranging from 4 cm to 11·5cm b/n male and female youngsters. The correlation b/n height and arm span was high ranging from 0·74 to 0·91 with P-value of <0·001. And arm span was presented to be the best predictor of height than other parameters(Monyeki et al., 2016).

As per to a study done on a sum of 1465 youngsters in India, standing height and arm span in young boys and girls was significantly correlated with each other. Pearson Correlation coefficient b/n height and arm span in young boys and girls was found to be 0.94 with p-value <0.001 and 0.96 with p-value <0.00 respectively. Linear regression model for estimation of height from arm span was generated: Height = 21.46 + 0.8192 x arm span (Snigdha et al., 2017 ).

Based on a study done among 244 youngsters aged 16-20 in Montenegro, arm span and standing height found to highly correlated with p-value of<0.05. The results also indicated that mean value of height and arm span in boys was found to be 182.49±6.81cm and 183.60±8.27 cm respectively, and in girls mean height was 168.14±6.30 and arm span was 167.07±7.36 cm (Marina Vucotic et al., 2018).

### *2.5.2 Correlation of arm length with stature*

According to a cross sectional study done in Bengali Hindu on a total of 240 children (116 boys and 124 girls) of aged 3-11 years, stature was found to be positively and significantly correlated with age (r =+0.886, p<0.01), arm length (r =+0.828, p<0.01) and other anthropometric parameters like arm span and tibial length among boys. Similarly, it was positively and significantly correlated with age (r = +0.829, p<0.01), arm length (r = +0.970, p<0.01) and their parameters among girls. The overall sex combined correlations between standing height and arm length (r = +0.894, p<0.01), were found to be statistically significant(Dorjee et al., 2016).

The result of a case-control cross sectional done in Dharavi, India among 141 children with mixed disabilities and 162 non-disabled control children of age 2-6 years showed that arm length ($R^2$ =0.81, P<0.001, n=162) was found to be strong predictor of height based on data from non-disabled control children. And this study also showed that the equations developed can be used for disabled children where the impairment hinder the measurement of standing height(Yousafzai et al., 2003).

A study done among 100 right handed Iranian medical students of age 20-26, reported that mean height and arm length in boys (176±6cm and 36.2±2.1 cm respectively) and arm length found to be strong predictor of stature with p<0.00.Similarly height and arm length in girls reported to be (162±6 cm and33.5±2.2 cm respectively) and also arm length was found to be a good predictor of stature in girls. Regression equation for estimation of stature from arm length was established: Male Stature (cm) = (Arm length x 1.886)+ 107.334 and Female Stature (cm) = (Arm length x 1.911)+ 98.099(Akhlaghi et al., 2012).

### 2.5.3 Correlation of tibial length with stature

According to a study done on random samples of 540 (270 male and 270 female) 0f age 17-21 in Gwalior region, India within Stature was estimated from tibial length statistically using simple regression analysis and multiplication factor. The outcome indicated that the mean tibial length for male was seen as 38.24 ± 2.343cm which was fundamentally (p<0.0001) higher than the females which was 36.064±2.464cm. The mean stature was 164.5±8.257cm and 155.3±5.854cm for male and female separately. The relapse model inferred for estimation of stature from tibial length in male was height =105.971+1.53 x (tibial length) ± 7.452 and for female was height = 103.76+1.43 x (tibial length) ± 4.69. The multiplication factor was also found to be good in predicting height of the study subjects with, it was 4.302 for male and 4.306 for female. There were huge positive correlation between's the stature and tibial length utilizing basic regression and multiplication factor (Akhilesh Trivedi et al., 2014).

In a school put together cross sectional investigation finished with respect to a sum of 240 kids (116 young men and 124 young ladies) of age 3-11 years and having a place with Bengali Hindu standing, stature was seen as significantly connected with age with Pearson correlation coefficient of 0.886 and p-value of <0.01and arm tibial length with Pearson correlation coefficient of 0.856 and p-value of <0.01 among young men. Essentially, it was emphatically and altogether associated with age with Pearson correlation coefficient of 0.82 and p-value of <0.01 and tibial length with Pearson correlation coefficient of 0.937 and p-value of <0.01 among young ladies. The overall sex combined correlations between height and age (R = 0.855, p-value <0.01) and height and tibial length(R = 0.890, p-value <0.01) were all found to be statistically significant(Dorjee et al., 2016).

Aftereffect of a case–control study done in Dharavi, India among 141 youngsters with mixed disabilities and 162 non-disabled control youngsters of age 2-6 years, tibia length ($R^2$=0.72, P<0.001) were seen as solid indicators of stature dependent on information from non-disabled control kids. And the outcome from the examination likewise demonstrated that regression models generated can be utilized for crippled youngsters where the disability impede the linear measurement of standing height(Yousafzai et al., 2003).

In another investigation directed on 400 subjects (200 male and 200 female) in the age bunch 17-24 years in India, the outcome demonstrated that correlation coefficient of 0.86 for guys and 0.85 for females. The coefficient of determination was 0.74 and 0.72 for guys and females respectively. The correlation between body height and percutaneous tibial length was measurably noteworthy (P- value<0.05) in guys and females (Khatun et al., 2016).

As indicated by a study carried out on a sum of 600 subjects within the age range of 21-45 in cross river state Nigeria, height was estimated from peri-cutaneustibial length. The result indicated that the mean PCTL was found to be 43.60 ± 2.3cm and 42.55 ± 2.83cm for male and female study participants respectively. The observed height was 165.80 ± 6.88 cm and 156.70 ± 6.06 cm for male and female, respectively. The simple regression equations computed for prediction of stature from tibial length for male and female subjects was found to be 64.78 ± 5.289(TL) and 23.28± 4.230(TL)), respectively(Esomonu et al., 2016).

As indicated by an examination directed from information assembled from longitudinal development study led by kid inquire about chamber in Denver, report of 67 subjects (31 young men and 36girls) inside the age scope of 3-10 years were utilized. The outcome demonstrated that estimation of stature from tibial length for unknown sex, stature=0.3462(tibial length) +39.512(cm) with mean tibial length of 230.38±2.30(mm)and coefficient of determination of 0.97.Similarly the regression model for estimation of stature from tibial length for young men and young ladies stature= 0.3581 (tibial length) + 37.213(cm)with mean tibial length of 231.62±1.73(mm)and coefficient of determination of 0.98 and stature=0.3475(tibial length) +39.641(cm) with mean tibial length of 233.83±2.57(mm) with coefficient of determination 0.97,respectively(Smith et al., 2007).

# 3. OBJECTIVE

## 3.1 General objective

- ✓ To estimate stature from arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia.

## 3.2 Specific objectives

- ✓ To assess the relationship between stature and arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia.
- ✓ To develop regression model for estimation of stature from arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia.
- ✓ To establish multiplication factor to estimate stature from arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia.
- ✓ To find out whether there is sexual dimorphism in estimation of stature from arm span, arm length, and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia.

# 4. MATERIALS AND METHODS

## 4.1 Study area

The study was completed in Addis Ababa, capital city of Ethiopia and the center point of African union. The city lies 9°1′48″N scope and 38°44′24″E longitude with an all out region of 540$Km^2$ and generally with subtropical climatic condition .Addis Ababa is a city with an extraordinary assorted variety and home of practically all ethnicities in the nation. The city includes 10 managerial sub cities in particular: Addis Ketema, AkakiKality, Arada, Yeka, Gulele, Nefas silk, Lideta,Bole, Kolfe Keranio, and Kirkos.

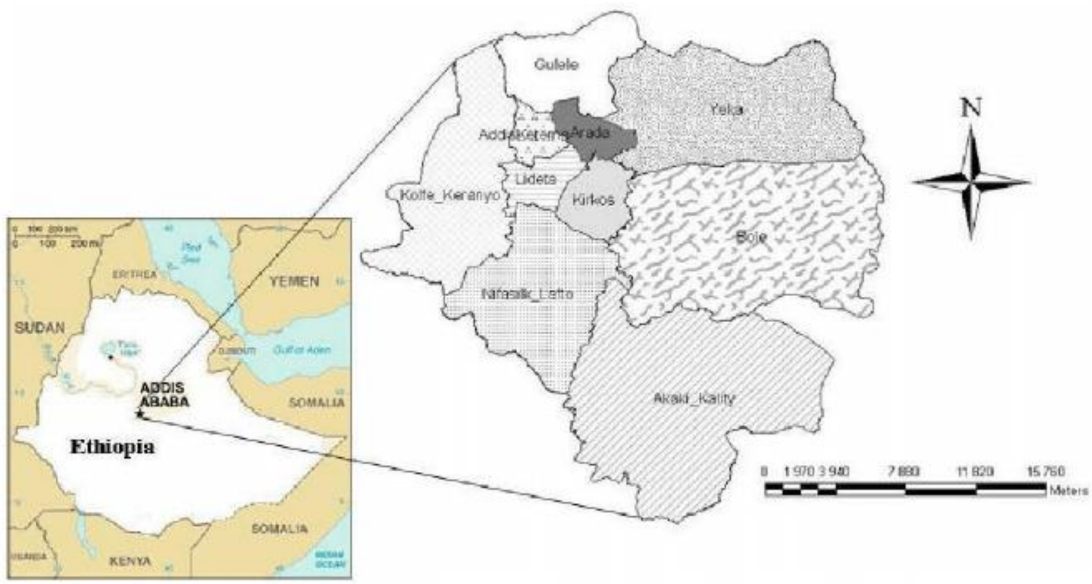


Figure 1: Location map of Addis Ababa, Ethiopia

According to 2018 Addis Ababa City Administration Education Bureau statistical report, in a total there are 1014 primary and secondary schools in all sub-cities comprising 795 primary, 83 secondary (9-10), 11 preparatory (11-12), 219 general secondary and preparatory (9-12). From these schools 297 are governmental, 717 are non-governmental.

## 4.2 Study period

The study was conducted from May-June, 2019

## 4.3 Study Design

High School based descriptive cross-sectional study was carried out among adolescents of age 15-18 in selected governmental and non-governmental high schools in Addis Ababa, Ethiopia.

## 4.4 Source population

The source populations for the study were all secondary and preparatory school adolescent students in Addis Ababa who were going to secondary school in the academic year 2011 E.C.

## 4.5 Study population

The study population for the study includes all regular high school adolescent students in selected non-governmental and government high schools of Addis Ababa who were going to high school in the scholarly year 2011E.C

## 4.6 Sample size determination

Formula for single population proportion was used to determine the sample size of the study. 95% level of significance and 5% margin of error were employed to determine the sample size of the study. There is no previous research done on estimation of stature from arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa so a proportion of 0.5 were used to calculate the sample size.

The formula used was the following:

$$n= \frac{(\mathbf{Z\alpha/2}\ )\mathbf{2P}\ (\mathbf{1-p})}{d^2}$$

**Where**

**P=** prevalence of the issue in the area.

**Zα/2** = critical value at 95% confidence level of certainty (1.96).

**d**= the margin of error between the sample and population.

**n**=is the required sample size

So, the sample size is-

$$n = \frac{(1.96)20.5(1 - 0.5)}{(0.05)^2}$$

n=384

- ✓ In addition to this non-response rate of 10% were added and the final sample size is 422.

## 4.7 Sampling Procedure

Multi-stage sampling method was employed to select samples that fulfill inclusion criteria. The total sample schools were all governmental and non-governmental general secondary schools (grade9 – 12) in Addis Ababa.

Among the general secondary schools including grade 9-12; 73 are governmental and 146 are non-governmental(bureau, 2018). An aggregate of 15 schools, 10 non-governmental and 5 governmental schools were chosen randomly. A sample of students was distributed proportionally between governmental and non-governmental schools by considering the size of students in each school using sample size allocation technique. Four sections from each chosen school at which one section from each grade level (grade 9 – 12) was selected randomly. Students were allocated proportionally to the size of students in each selected section. Finally, Study subject were selected from selected sections by systematic random sampling technique using student list.

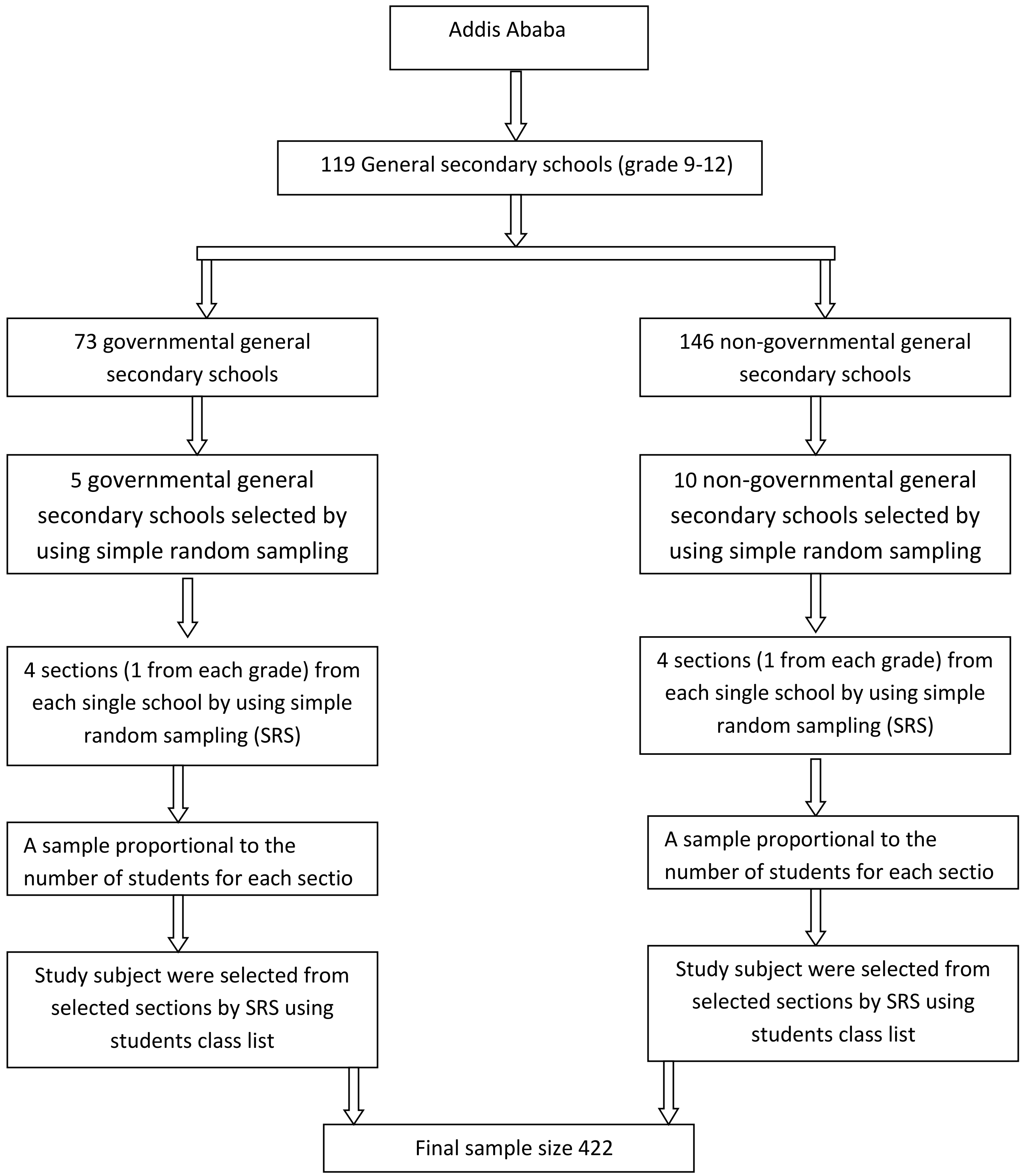
Addis Ababa
119 General secondary schools (grade 9-12)
73 governmental general secondary schools
146 non-governmental general secondary schools
5 governmental general secondary schools selected by using simple random sampling
10 non-governmental general secondary schools selected by using simple random sampling
4 sections (1 from each grade) from each single school by using simple random sampling (SRS)
4 sections (1 from each grade) from each single school by using simple random sampling (SRS)
A sample proportional to the number of students for each sectio
A sample proportional to the number of students for each sectio
Study subject were selected from selected sections by SRS using students class list
Study subject were selected from selected sections by SRS using students class list
Final sample size 422

**Figure 2: Schematic presentation of sampling procedure**

## 4.8 Inclusion and Exclusion Criteria

### 4.8.1 Inclusion criteria

- ✓ All regular high school adolescent students of age 15-18 in selected governmental and non-government general secondary schools of Addis Ababa and willing to take part in the investigation were considered as inclusion criteria for the study.

### 4.8.2 Exclusion criteria

- ✓ Subjects having spinal and limb deformities which have an effect on standing height, arm span, arm length and tibial length, such as lordosis, kyphosis, scoliosis, bowing of legs and flattening of the plantar arch and having history of physical damage or loss of extremities were considered as excluded from the study.

## 4.9 Study variables

### 4.9.1 Dependent variable

- ✓ Stature

### 4.9.2 Independent variables

- ✓ Age
- ✓ Sex
- ✓ Arm span
- ✓ Arm length
- ✓ Tibial length

## 4.10 Operational definition

Stature: -is a natural height of a person in an upright position.

Anatomical anthropometric parameters:-arm span, arm length, tibial length and stature.

Arm span is a measurement taken from the tip of the middle finger (dactylion) of one arm to the tip middle finger (dactylion) of another arm when the arms are outstretched.

Arm length is a measurement taken from the acromion of humerus of one arm to tip of the middle finger (dactylion) of similar arm.

Tibial length is a measurement taken from the medial shallowest point on upper border of medial condyle of tibia to tip of medial malleolus of one leg.

Frankfurt horizontal plane is a plane connecting the highest point on the upper border of the opening of each external auditory canal and the low point on the lower border of the orbit and that is used to orient a human head in horizontal plane.(Digssie et al., 2018).

## 4.11 Data collection and measurements

The data were gathered through interviewer-administered questionnaire and measurements of anthropometric parameters. Anthropometric measurements were taken at the end of the interview. Data were collected by five postgraduate students who were enlisted and trained for this study. According to (Marfell-Jones et al., 2006) the protocol of the International Society for the Advancement of Kinanthropometry (ISAK) were used for the measurements of all anthropometric parameters.

Stature was measured utilizing a convenient stadiometer and recorded to the closest 0.1 cm. During stature measurement the subjects stood shoeless on the stadiometer and pins and interlaces from the hair were expelled to stay away from their impact on measurement of height. Stature was estimated with the head of study participants in a Frankfurt Plane, knees straight, and the heels, backside, and the shoulders contacting the vertical surface of the Stadiometer. Stature was measured 2 times and the average was taken.

Weight was measured with standard mechanical balance and recorded to the closest of 0.1kg

Arm span measurement were taken from the tip of the center finger of one arm to the tip of the center finger of the other arm (dactylion to dactylion) with the arms outstretched at right angle of 180˚ to the body and elbows and wrists expanded, and the palms confronting directly forward. During the measurement, all study participants remain with their back adjusted to the vertical surface of the stadiometer and the readings were recorded to the closest 0.1 cm. Arm span were measured 2 times and the average was taken.

Arm length were taken from the tip of humerus (acromion) bone to tip of the center finger (dactylion) of right and left arms while the subject is standing erect and the head of the subject in the Frankfurt horizontal position with arms hanging down wards parallel to the body. And the readings were recorded to the closest of 0.1 cm. Arm length was measured 2 times and the average was taken.

Tibial length was measured from the medial most shallow point on upper border of medial condyle of tibia and tip of medial malleolus of the both legs while the subject is standing erect and head of the subject in the Frankfurt horizontal plane and the readings were recorded to the closest of 0.1 cm. Tibial lengths were measured 2 times and the average was taken.

## 4.12 Data quality control

The data were gathered by five trained data collectors. To maintain data quality, training was given for data gatherers. On site Supervision were done by the principal investigator during data gathering. Just complete information was utilized for investigation.

## 4.13 Ethical consideration

In the first place, moral ethical clearance was acquired from the Department of Anatomy, College of Health Science, and Addis Ababa University Institutional Review Board. Consent was gotten from Education Departments of sub-cities and principals of Schools to be examined.

Both composed and verbal informed assent was gotten from study subjects after the information gatherers clarified the point of the examination and the way that it has no intrusive methodology and damage on the investigation participants. Respondents were told to leave the examination whenever they need and they were told that data is recorded without their name being referenced. Just codes were utilized to keep it unknown and keep up secrecy and protection of respondents.

### 4.14 Data processing and statistical analysis

Data were edited, coded, and entered into Epi-Data version 4.4.3.1 and were exported for cleaning and analyses to SPSS for windows version 23. Descriptive analyses were conducted and the result was introduced utilizing tables and figures. P-value of <0.05 were used to declare Statistical significance. Bilateral asymmetries in the measurement between sexes were evaluated using dependent t-tests.

The linear relationship between the stature and the independent variables was checked by establishing scatter plot matrix and the magnitude of relationship was obtained by computing Pearson correlation coefficient(R).

Simple and multiple linear regression models were computed to estimate the height of youngsters from arm span, arm length and tibial length. In addition to the regression equations multiplication factors were generated for each of the parameters. The accuracy of stature prediction of each regression equation was assessed by computing standard error of the estimate (SEE) and coefficient of determination (R).

Before conducting analysis of the present data several tests for basic assumptions of linear regression and reliability analysis were taken into consideration.

Cronbach's Alpha result was computed to check the reliability of the present data. In the present investigation the computed value of Cronbach’s alpha was found to be 0.911 which shows that there was high internal consistency between all items in the questionnaire.

Statistical test for basic assumption of linear regression includes tests of linearity, tests of homoscedasticity and tests of normality.

Linearity of the anthropometric variables in the data set was assessed by computing the correlation coefficient and significance of association between the dependent variable (stature) and the independent variables (arm span, arm length and tibial length). The data set shows that the variables are linearly associated for most of the anthropometric parameters with significance of < 0 .000. The next assumption of linear regression considered in the present study is test of homoscedasticity and assessed by generating scatter plot for the residual for dependent variables.

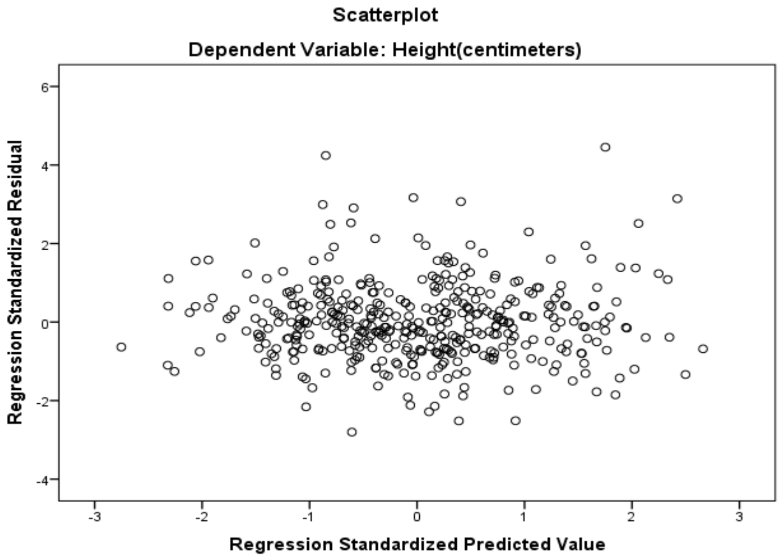


**Figure 3:- Scatter plot of residuals distribution for height**

Scatter plot above shows that the residuals are evenly distributed between values and the data set is homoscedastic. Normal distributions of the anthropometric parameters were assessed by computing skewness and kurtosis of the variables.

The coefficient of skewness and kurtosis for standing height in the present investigation were .361 and .375 respectively. Both the results were between -1 and 1 this indicates that the anthropometric parameter is normally distributed. Normality of distribution for the remaining anthropometric parameters was checked by establishing histogram plot.

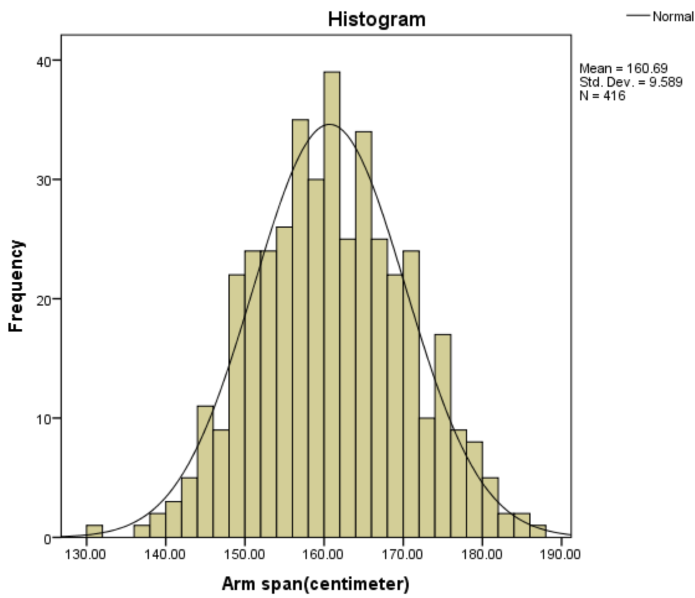


**Figure4: - Distribution of arm span among adolescent in Addis Ababa, Ethiopia**

# 5. RESULT

## 5.1 Socio demographic characteristics of the respondents

Table 1 below describes that, out of the sampled 422 adolescent students, a total of 416 participated in this study with a response rate of 98.57%. Out of the total adolescents 226(54.3%) were from governmental schools and the remaining 190(45.7%) were from non-governmental schools. Among total respondents, 307(73.8%) were Orthodox Christian followed by protestant 52 (12.5%) and Muslim 37(8.9%). Socio demographic index of the present study shows that there were 202 (48.6%) males and 214 (51.4%) female respondents and all of the adolescents are from grade 9-12.

**Table 1: Socio-demographic characteristics of respondents in Addis Ababa, Ethiopia,2019**

| SN | Variable | Response | Number | Percent (%) |
|---|---|---|---|---|
| 1 | Sex | Male | 202 | 48.6 |
| | | Female | 214 | 51.4 |
| 2 | Age in full year | 15 | 102 | 24.5 |
| | | 16 | 103 | 24.8 |
| | | 17 | 106 | 25.5 |
| | | 18 | 105 | 25.2 |
| 3 | Grade level | 9th | 109 | 26.2 |
| | | 10th | 102 | 24.5 |
| | | 11th | 103 | 24.8 |
| | | 12th | 102 | 24.5 |
| 4 | School type | Governmental | 226 | 54.3 |
| | | Non-governmental | 190 | 45.7 |
| 5 | Religion | Orthodox Christian | 307 | 73.8 |
| | | Protestant | 52 | 12.5 |
| | | Muslim | 37 | 8.9 |
| | | Catholic | 10 | 2.4 |
| | | Others | 10 | 2.4 |

| | | | | |
|---|---|---|---|---|
| 6 | Region | Addis Ababa | 378 | 90.9 |
| | | Amhara | 14 | 3.4 |
| | | Oromiya | 12 | 2.9 |
| | | Tigray | 5 | 1.2 |
| | | SNNPR | 4 | 1.0 |
| | | Harreri | 3 | 0.7 |
| 7 | Family size | 1-5 | 276 | 66.3 |
| | | >5 | 140 | 33.7 |

## 5.2 Descriptive statistics of anthropometric parameters in male and female adolescents

Descriptive statistics for stature/standing height, weight, body mass index and anatomical anthropometric measurements of male adolescents is provided in table 2. In the present study it was observed that standing height of study participants ranged from 136.5 cm to 192.0 cm and its mean was 164.36 ± 8.89 cm in male study participants. In male adolescents, it was also observed that weight ranged from 32kg to 51.99 kg and mean weight was 51.99 ± 7.60 kg.

**Table 2: Descriptive statistics of stature, anatomical anthropometric parameters, weight, and body mass index of male participants in Addis Ababa, Ethiopia, 2019**

| Parameters | Minimum | Maximum | Mean | Standard deviation(SD) |
|---|---|---|---|---|
| Height(CM) | 136.50 | 192.0 | 164.36 | 8.89 |
| Weight(Kg) | 32.00 | 80.10 | 51.99 | 7.60 |
| Arm span(CM) | 131.50 | 186.10 | 165.70 | 9.46 |
| Rt arm length(CM) | 64.20 | 88.90 | 76.74 | 4.67 |
| Lt arm length(CM) | 64.10 | 88.30 | 76.65 | 4.64 |
| Rt tibial length(CM) | 32.10 | 47.30 | 40.31 | 2.91 |
| Lt tibial length(CM) | 32.00 | 48.20 | 40.44 | 2.95 |
| BMI ($Kg/M^2$) | 14.32 | 30.78 | 19.25 | 2.53 |

Descriptive statistics for Height/standing height, weight, body mass index and anatomical anthropometric measurements of female adolescents is provided in table 3. In the present study it was observed that height ranged from 143.00 cm to 176.00 cm and its mean was 155.75 ± 5.86 cm in female adolescents. Moreover, it was also observed that weight ranged from 34kg to 68.80 kg and its mean was 49.62 ± 7.15 kg.

**Table 3: Descriptive statistics of stature, weight, anatomical anthropometric parameters, and body mass index of female participants in Addis Ababa, Ethiopia**

| Parameters | Minimum | Maximum | Mean | Standard deviation(SD) |
|---|---|---|---|---|
| Height(CM) | 143.00 | 176.00 | 155.75 | 5.86 |
| Weight(Kg) | 34.00 | 68.80 | 49.62 | 7.15 |
| Arm span(CM) | 136.20 | 172.50 | 155.96 | 6.95 |
| Rt arm length(CM) | 63.10 | 82.00 | 72.49 | 3.48 |
| Lt arm length(CM) | 63.00 | 82.00 | 72.42 | 3.42 |
| Rt tibial length(CM) | 31.90 | 44.70 | 37.85 | 2.26 |
| Lt tibial length(CM) | 32.10 | 44.10 | 37.90 | 2.23 |
| BMI($Kg/M^2$) | 14.81 | 29.61 | 20.47 | 2.93 |

Out of the total 202 male and 214 female adolescents 59.90% of male and 73.36% of female adolescents have normal body mass index (18.5 to 24.9 $kg/m^2$). Moreover, it was also observed that 36.14% of male and 19.16% female adolescents were under weight. And also3.47% of male and 7.48% of female adolescents were overweight respectively.

Table 4 below illustrates that the distribution of study participants on the basis of standing height and arm span. In the present study 1.5% of male and 5.6% of female participants have equal measurement of height and arm span. Moreover, it also showed that most 60.4% of male and 55.1% of female adolescents have higher measurement of height than arm span.

**Table 4: Distribution of study participants on the basis of height and arm span in Addis Ababa, Ethiopia**

| Groups | Male | Female | Total |
|---|---|---|---|
| Height = Arm span | 3(1.5%) | 12(5.6%) | 15(3.6%) |
| Height < Arm span | 77(38.1%) | 84(39.3%) | 161(38.7%) |
| Height > Arm span | 122(60.4%) | 118(55.1%) | 240(57.6%) |
| Total | 202(100%) | 214(100%) | 416(100%) |

## 5.3 anthropometric parameters and Stature difference between male and female adolescents

Independent sample t-test was generated to illustrate the strength of sexual dimorphism of standing height and anatomical anthropometric measurements. Table 5 describes comparison of mean value of anatomical anthropometric measurements, BMI, stature and weight between male and female adolescents. In the present study it was evident that overall mean value of height and most of anatomical anthropometric measurements of male adolescents were found to be greater than that of their female counter parts. But it was known that the mean value of BMI of female adolescents were greater than of their male counter parts and all these differences were statistically significant with p-value <0.05.

**Table 5: Comparison of means of all measurements between male and female participants in Addis Ababa, Ethiopia, 2019**

| | Independent t-test for equality of means | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 95% CI | |
| Parameters | T | DF | Sig | MD | SED | Lower | Upper |
| Height(Cm) | 11.714 | 414 | .000 | 8.606 | .7347 | 7.162 | 10.051 |
| Weight(Kg) | 3.276 | 414 | .001 | 2.371 | .7239 | .948 | 3.794 |
| Arm span(Cm) | 12.001 | 414 | .000 | 9.735 | .8112 | 8.140 | 11.330 |
| Rt arm length | 10.547 | 414 | .000 | 4.248 | .4028 | 3.456 | 5.040 |
| Lt arm length | 10.626 | 414 | .000 | 4.234 | .3984 | 3.450 | 5.017 |
| Rttibial length | 9.623 | 414 | .000 | 2.456 | .2552 | 1.954 | 2.958 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Lt tibial length | 9.939 | 414 | .000 | 2.539 | .2555 | 2.037 | 3.041 |
| BMI | -4.546 | 414 | .000 | -1.223 | .2691 | -1.752 | -.694 |

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 Bilateral asymmetry of right and left anatomical anthropometric measurements

Dependent sample t-test was generated for male and female adolescents to assess the presence and strength of bilateral asymmetry between left and right anatomical anthropometric parameters. Both arm length and tibial length illustrated no statistically significant bilateral asymmetry for male adolescents.

In contrary to the male adolescents, dependent sample t-test of females illustrated significant bilateral asymmetry in right and left tibial length, where tibial length on the left side was higher than the right side. The mean value of arm length in females was insignificantly higher on the right side than the left side.

**Table 6: Bilateral asymmetry of anatomical anthropometric parameters of female participants in Addis Ababa, Ethiopia, 2019**

| Bilateral Parameters (CM) | Dependent sample t-test for females | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 95% CI | | | | |
| | | | | Lower | Upper | | | |
| | Mean | SD | SEM | | | T | DF | Sig |
| Rt arm length- Lt arm length | .0876 | .727 | .0511 | -.0132 | .1885 | 1.713 | 201 | .088 |
| Rttibial length- Lt tibial length | -.1341 | .550 | .0387 | -.210 | -.0577 | -3.462 | 201 | .001 |

SD-standard deviation SEM-standard error of measurement CI-confidence interval T-t statistics DF-degree of freedom Sig-significance Rt-right Lt-left

## 5.5 Correlation between standing height and anatomical anthropometric parameters

Pearson's correlation coefficient (R) between height and anatomical anthropometric measurements for male and female adolescents is provided in Table 7. The Pearson's correlation coefficient between height and all anatomical anthropometric measurements of male adolescents ranged from 0.738 for right tibial length to 0.843 for arm span and also R-value of female adolescents ranged from 0.599 for left tibial length to 0.708 for arm span. All anatomical anthropometric measurements and weights of male and female adolescents showed positive and statistically significant R-value with height with p-value < 0.05. For both males and females, the highest correlation was depicted in arm span. However lowest correlation was exhibited in right tibial length and left tibial length for male and female adolescents respectively. The R- value for all anatomical anthropometric parameters was greater in male adolescents than that of females.

**Table 7: Correlation of height with anatomical anthropometric parameters, weight and body mass index of male and female participants in Addis Ababa, Ethiopia, 2019**

| Parameters | Male-202 | | Female-214 | |
|---|---|---|---|---|
| | Stature | | Stature | |
| | R | P-value | R | P-value |
| Weight(Kg) | .523 | .000 | .293 | .000 |
| Arm span(CM) | .843 | .000 | .708 | .000 |
| Rt arm length(CM) | .806 | .000 | .635 | .000 |
| Lt arm length(CM) | .813 | .000 | .636 | .000 |
| Rt tibial length(CM) | .738 | .000 | .611 | .000 |
| Lt tibial length(CM) | .744 | .000 | .599 | .000 |
| BMI($Kg/M^2$) | -.226 | .051 | -.225 | .062 |

However, body mass index (BMI), R = -0.226 for males and R = -0.225 for females, was not significantly correlated with height of males and females. For both male and female adolescents, body mass index was negatively correlated with height even though it did not have significant association.

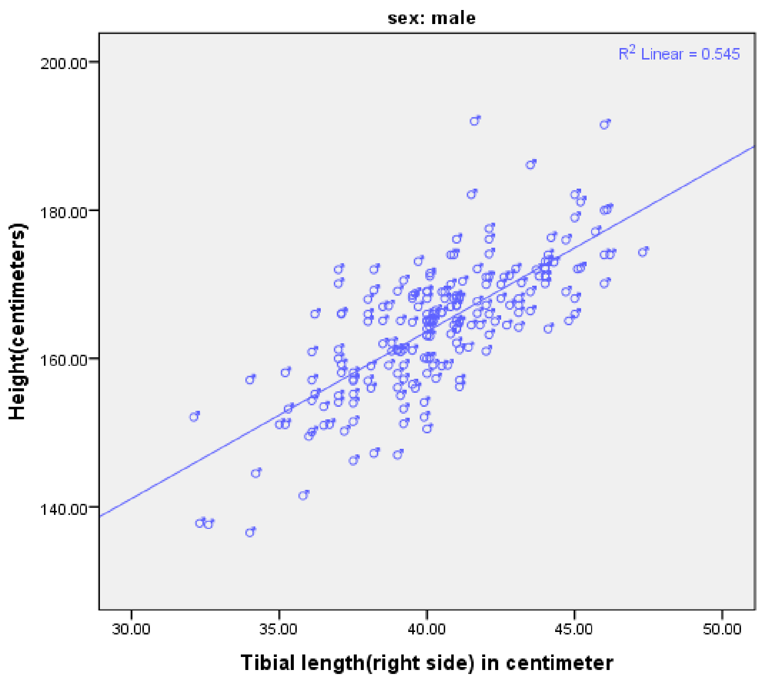


**Figure 5: Scatter plot between height and right side tibial length of male participants in Addis Ababa, Ethiopia, 2019**

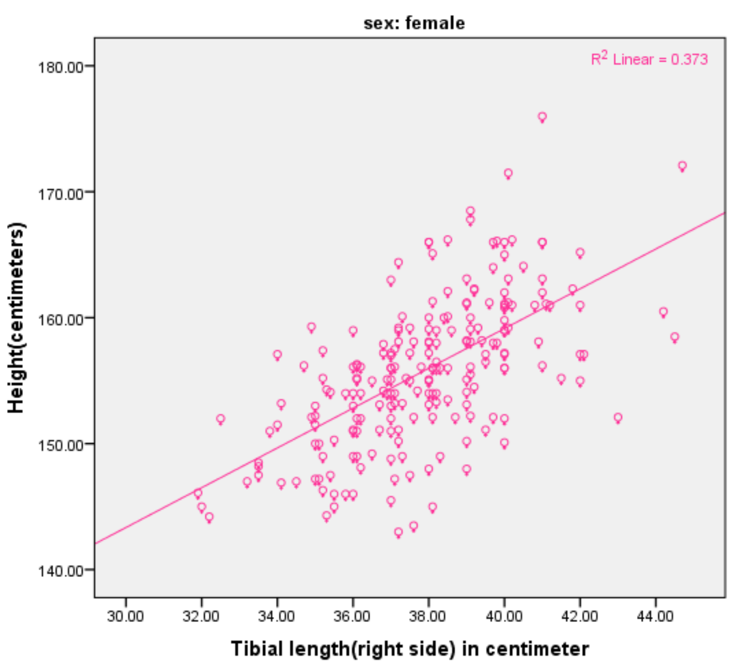

**Figure 6: Scatter plot between height and right side tibial length of female participants in Addis Ababa, Ethiopia, 2019**

The fit regression line showed the relationship between height and right length tibial for male and female adolescents respectively with dispersion from the line at $R^2$ linear = 0.545 for male and $R^2$ linear =0.373 for female adolescents (Figure 6).

## 5.6 Stature estimation from anatomical anthropometric parameters

Multiplication factor, simple linear regression and multiple linear regression models were separately generated for male and female adolescents to estimate stature from different anatomical anthropometric parameters.

### 5.6.1. Multiplication factors (MF) to estimate height from anatomical anthropometric parameters

Table 8 below illustrates about mean value of multiplication factors for each anatomical anthropometric parameters of male and female adolescents. For example, mean multiplication factors for arm span, right arm length, left arm length, right tibial length and left tibial length of male adolescents were 0.992 cm, 2.143 cm, 2.146 cm, 4.086 and 4.073 cm respectively. And mean multiplication factors for arm span, right arm length, left arm length, right tibial length and left tibial length in female adolescents were 0.999 cm, 2.151 cm,2.153 cm, 4.123 and 4.117 cm respectively.

**Table 8: Multiplication factor for each anatomical anthropometric parameter of male and female participants in Addis Ababa, Ethiopia, 2019**

| Parameters | Male-202 | | | Female-214 | | |
|---|---|---|---|---|---|---|
| | Mean | MF | | Mean | MF | |
| | | Mean | SD | | Mean | SD |
| Arm span(CM) | 165.70 | .992 | .030 | 155.96 | .999 | .032 |
| Rt arm length(CM) | 76.74 | 2.143 | .077 | 72.49 | 2.151 | .082 |
| Lt arm length(CM) | 76.65 | 2.146 | .075 | 72.42 | 2.153 | .081 |
| Rt tibial length(CM) | 40.31 | 4.086 | .201 | 37.85 | 4.123 | .194 |
| Lt tibial length(CM) | 40.44 | 4.073 | .200 | 37.90 | 4.117 | .193 |

### 5.6.2 Simple linear regression equations to estimate of stature from anatomical anthropometric parameters for male adolescents

Simple Linear regression equations were generated and provided in table 9 for each anatomical anthropometric measurement to estimate height for male participants. The Pearson correlation coefficient was largest in arm span and smallest in left arm length. Whereas the smallest standard error of estimate (SEE) value was observed in left arm length and largest value was in right tibial length.

Simple regression equations computed to estimate stature for male participants using arm span was Height = 33.11+0.792(Arm span) with R = 0.843 and using left arm length was Height = 45.04+1.55(Left arm length) with R=0.636.

All the anthropometric parameters significantly estimated the standing height of adolescents with significance of P<0.000.

| Parameters | R | $R^2$ | Adjusted $R^2$ | SEE | Regression equation | sig. |
|---|---|---|---|---|---|---|
| Arm span(CM) | .843 | .711 | .710 | 4.790 | 33.11+0.792(AS) | .000 |
| Rt arm length(CM) | .806 | .649 | .647 | 5.280 | 46.71+1.53(RAL) | .000 |
| Lt arm length(CM) | .636 | .404 | .401 | 4.541 | 45.04+1.55(LAL) | .000 |
| Rt tibial length(CM) | .738 | .545 | .543 | 6.012 | 73.53+2.25(RTL) | .000 |
| Lt tibial length(CM) | .744 | .553 | .551 | 5.958 | 73.70+2.24(LTL) | .000 |

**Table 9: Estimation of stature from anatomical anthropometric parameters of male participants in Addis Ababa, Ethiopia, 2019**

Rt-right Lt-left AS-arm span RAL- right arm length LAL-left arm length RTL-right tibial length LTL-left tibial length R-correlation coefficient$R^2$-coefficient of determination

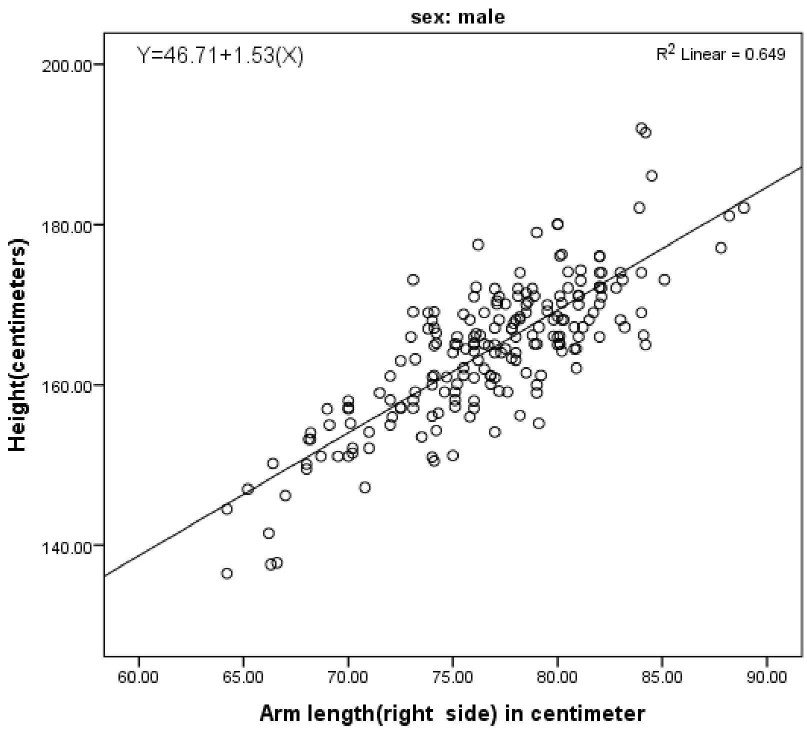


**Figure 7: Regression line between height and right-side arm length of male participants in Addis Ababa, Ethiopia, 2019**

The regression line for right arm length with height was drawn from data analysis of male adolescents. This scatter plot illustrates that there is linear relationship between right arm length and stature of adolescents. And stature of adolescents increases with increase in right arm length and vice versa.

### 5.6.3 Simple linear regression equations to estimate of stature from anatomical anthropometric parameters for female adolescents

Simple Linear regression equations were formulated for each anatomical anthropometric measurement to estimate stature for female participants. Estimation of statures from each anatomical anthropometric measurement of female participants is provided in table 10. The R-value was largest in arm span and smallest in left tibial length. Whereas the smallest SEE value was observed in arm span and largest value was in left tibial length (Table 10).

Simple regression model to estimate stature for female participants using arm span was height = 62.59+0.792(Arm span) with R = 0.708and the regression model to estimate height from left tibial length was height = 95.99+1.57(Left tibial length) with R=0. 599. All the anthropometric parameters significantly estimated the standing height of adolescents with significance of P<0.000.

**Table 10: Estimation of stature from anatomical anthropometric parameters of female participants in Addis Ababa, Ethiopia, 2019**

| Parameters | R | $R^2$ | Adjusted $R^2$ | SEE | Regression equation | sig. |
|---|---|---|---|---|---|---|
| Arm span(CM) | .708 | .501 | .499 | 4.153 | 62.59+0.597(AS) | .000 |
| Rt arm length(CM) | .635 | .403 | .400 | 4.546 | 78.36+1.06(RAL) | .000 |
| Lt arm length(CM) | .636 | .404 | .401 | 4.541 | 76.79+1.09(LAL) | .000 |
| Rttibial length(CM) | .611 | .373 | .370 | 4.654 | 95.96+1.58(RTL) | .000 |
| Lt tibial length(CM) | .599 | .359 | .356 | 4.710 | 95.99+1.57(LTL) | .000 |

Rt-right Lt-left AS-arm span RAL- right arm length LAL-left arm length RTL-right tibial length LTL-left tibial length R-correlation coefficient$R^2$-coefficient of determination

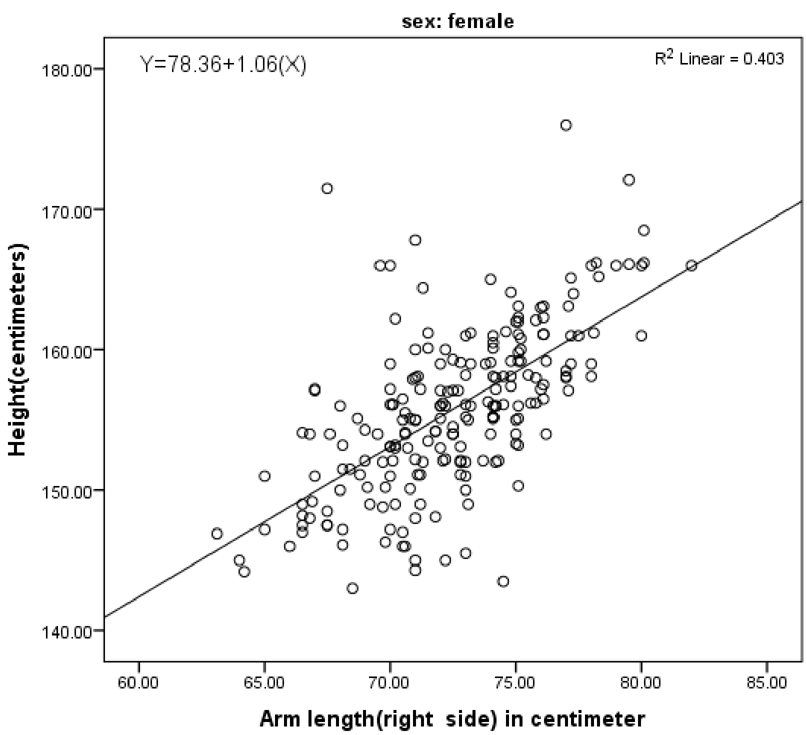


**Figure 8: Regression line between height and right-side arm length of female participants in Addis Ababa, Ethiopia, 2019**

The regression line and coefficient of determination for right arm length with height was drawn from data analysis of female adolescents. This scatter plot illustrates that there is linear relationship between right arm length and standing height of adolescents. And stature of adolescents increases with increase in right arm length and vice versa.

### 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 female participants. Table 11 illustrated estimation of stature by combination of bilateral and different anatomical anthropometric measurements of female participants.

The largest R-value was 0.874 for combination of arm span (AS), Right arm length (RAL) and Left tibial length (LTL). The smallest R-value was 0.745 for combination of Right and left tibial length (RTL and LTL). The largest SEE was exhibited by combination of Right and left tibial length (RTL and LTL) which was 5.962. The smallest SEE value was exhibited by combination of arm span (AS), Right arm length (RAL) and Left tibial length (LTL) which was 4.347.

Multiple regression models to estimate stature of male participants from combination of all anatomical anthropometric parameters were illustrated in the table below.

Combinations of anatomical anthropometric parameters are statistically significant in estimating the stature of female adolescents with $P<0.00$

**Table 11: Estimation of stature from combination of anatomical anthropometric parameters of male participants in Addis Ababa, Ethiopia, 2019**

| Parameters(cm) | R | $R^2$ | Adjusted $R^2$ | SEE | Durbin-Watsor | Regression equation | sig. |
|---|---|---|---|---|---|---|---|
| AS-RAL | .852 | .726 | .723 | 4.670 | 1.924 | 31.05+0.56(AS)+0.50(RAL) | .000 |
| AS-LAL | .855 | .731 | .728 | 4.633 | 1.954 | 30.45+0.53(AS)+0.58(LAL) | .000 |
| AS-RTL | .869 | .756 | .754 | 4.413 | 1.745 | 28.71+0.60(AS)+0.89(RTL) | .000 |
| AS-LTL | .872 | .761 | .758 | 4.372 | 1.806 | 28.70+0.59(AS)+0.92(LTL) | .000 |
| RAL-LAL | .813 | .662 | .658 | 5.198 | 2.054 | 44.94+0.17(RAL)+1.38(LAL) | .000 |
| RTL-LTL | .745 | .555 | .550 | 5.962 | 1.714 | 72.99+0.66(RTL)+1.59(LTL) | .000 |
| LAL-RTL | .841 | .707 | .704 | 4.840 | 1.972 | 40.05+0.94(RTL)+1.12(LAL) | .000 |
| RAL-LTL | .842 | .710 | .707 | 4.815 | 1.995 | 40.22+1.04(LTL)+1.06(RAL) | .000 |
| AS-RAL-LTL | .874 | .764 | .761 | 4.347 | 1.866 | 27.97+0.49(AS)+0.27(RAL)+ 0.85(LTL) | .000 |
| AS-LAL-RTL | .873 | .761 | .758 | 4.374 | 1.828 | 27.79+0.48(AS)+0.32(LAL)+ 0.78(RTL) | .000 |

### 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 illustrated estimation of stature by combination of bilateral and different anatomical anthropometric measurements of female participants.

The largest R-value was 0.742 for combination of arm span (AS), Left arm length (LAL) and Right tibial length (RTL). The smallest R-value was 0.611 for combination of Right and left tibial length (RTL and LTL). The largest SEE was exhibited by combination of Right and left tibial length (RTL and LTL) which was 4.688. The smallest SEE value was exhibited by combination of arm span (AS), Left arm length (LAL) and Right tibial length (RTL) which was 3.960. Combinations of anatomical anthropometric parameters are statistically significant in estimating the standing height of female adolescents with $P<0.00$.

**Table 12: Estimation of stature from combination of anatomical anthropometric parameters of female participants in Addis Ababa, Ethiopia, 2019**

| Parameters(cm) | R | $R^2$ | Adjusted $R^2$ | SEE | Durbin-Watson | Regression equation | sig. |
|---|---|---|---|---|---|---|---|
| AS-RAL | .712 | .507 | .502 | 4.139 | 1.846 | 60.97+0.50(AS)+0.233(RAL) | .000 |
| AS-LAL | .714 | .509 | .505 | 4.129 | 1.852 | 60.10+0.48(AS)+0.27(LAL) | .000 |
| AS-RTL | .741 | .549 | .544 | 3.961 | 1.883 | 58.12+0.45(AS)+0.70(RTL) | .000 |
| AS-LTL | .740 | .547 | .543 | 3.969 | 1.889 | 57.23+0.46(AS)+0.70(LTL) | .000 |
| RAL-LAL | .640 | .410 | .404 | 4.529 | 1.767 | 76.25+0.50(RAL)+0.58(LAL) | .000 |
| RTL-LTL | .611 | .373 | .367 | 4.668 | 1.852 | 95.73+1.44(RTL)+0.14(LTL) | .000 |
| LAL-RTL | .697 | .486 | .482 | 4.225 | 1.808 | 68.38+0.72(RAL)+0.92(RTL) | .000 |
| RAL-LTL | .693 | .481 | .476 | 4.250 | 1.798 | 68.72+0.72(RAL)+0.90(LTL) | .000 |
| AS-RAL-LTL | .740 | .548 | .542 | 3.972 | 1.877 | 56.61+0.41(AS)+0.11(RAL)+ 0.68(LTL) | .000 |
| AS-LAL-RTL | .742 | .551 | .545 | 3.960 | 1.854 | 56.95+0.39(AS)+0.15(LAL)+ 0.68(RTL) | .000 |

## 5.7 Comparison of actual and estimated height of adolescents

### 5.7.1 Paired t-test to compare mean difference between actual stature and estimated stature among male participants

Students paired sample t-test was done to compare the presence of mean difference between actual and estimated stature from different anatomical anthropometric measurements in male participants. For all anatomical anthropometric parameters, there were statistically insignificant difference (p>0.05) between mean values of estimated statures and actual statures in male adolescents. For instance, mean values of actual standing height and estimated stature by arm span in males were 164.364 ± 8.890 cm and 164.358 ±7.221 cm respectively, and mean height difference at (T =0.0174, DF = 201) was statistically insignificant (p>0.05).

### 5.7.2Paired t-test to compare mean difference between actual stature and estimated stature among female participants

Similar test was 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 adolescents. For instance, mean values of actual and estimated stature by arm span in female adolescents were155.757± 5.868cm and 155.759 ±5.307 cm respectively, and mean height difference at (T = -.034, DF = 214) was statistically insignificant (p>0.05).

## 5.8 Age specific statistical models to estimate stature from anthropometric parameters

In order to cope up with the problem of age related loss of height and other anthropometric parameters, age specific Pearson correlation coefficient, regression models and multiplication factors were computed.

### 5.8.1 Age specific Correlation, regression model and multiplication factor to estimate stature from anatomical anthropometric parameters for adolescents of age 15

Age specific Pearson's correlation coefficient (R) and simple linear regression equations were formulated for each anatomical anthropometric measurement to estimate stature for study participants. Multiplication factor for all anthropometric parameters were computed and provided in table 13 A correlation coefficient and regression model to estimate statures from each anatomical anthropometric measurement of adolescents of age 15 is provided in table 14. The R-value was largest in arm span and smallest in right tibial length. All anatomical anthropometric parameters were significantly correlated with standing height of adolescents of age 15 with P<0.00. Age specific multiplication factor were also computed to estimate stature of adolescents of age 15.

**Table-13: Multiplication factor for each of anatomical anthropometric parameters of adolescents of age 15 in Addis Ababa, Ethiopia, 2019**

| Parameters | Male-49 | | | Female-53 | | |
|---|---|---|---|---|---|---|
| | Mean | MF | | Mean | MF | |
| | | Mean | SD | | Mean | SD |
| Arm span(CM) | 162.74 | .993 | .029 | 154.58 | .997 | .027 |
| Rt arm length(CM) | 75.01 | 2.155 | .085 | 72.10 | 2.139 | .076 |
| Lt arm length(CM) | 74.94 | 2.157 | .086 | 71.89 | 2.146 | .074 |
| Rttibial length(CM) | 39.99 | 4.045 | .178 | 37.37 | 4.131 | .177 |
| Lt tibial length(CM) | 40.08 | 4.045 | .178 | 37.34 | 4.131 | .177 |

MF-multiplication factor SD-Standard deviation

**Table 14: Correlation and regression models to estimate stature from anatomical anthropometric parameters of adolescents of age 15 in Addis Ababa, Ethiopia, 2019**

| Parameters | R | $\mathbf{R^2}$ | Adjusted $\mathbf{R^2}$ | SEE | Regression equation | sig. |
|---|---|---|---|---|---|---|
| Arm span(CM) | .895 | .801 | .799 | 4.056 | 31.91+0.793(AS) | .000 |
| Rt arm length(CM) | .812 | .660 | .656 | 5.303 | 43.26+1.556(RAL) | .000 |
| Lt arm length(CM) | .817 | .667 | .664 | 5.246 | 43.34+1.558(LAL) | .000 |
| Rttibial length(CM) | .806 | .650 | .647 | 5.377 | 59.80+2.533(RTL) | .000 |
| Lt tibial length(CM) | .814 | .662 | .659 | 5.282 | 62.04+2.473(LTL) | .000 |

### 5.8.2 Age specific Correlation, regression model and multiplication factor to estimate standing height from anatomical anthropometric parameters for adolescents of age 16

Age specific Pearson's correlation coefficient (R) and simple linear regression equations were formulated for each anatomical anthropometric measurement to estimate stature for study participants. The R-value was largest in arm span and smallest in left tibial length. All anatomical anthropometric parameters were significantly correlated with standing height of adolescents of age 16 with P<0.00

Age specific multiplication factor were also computed to estimate standing height of adolescents of age 16.

**Table 2: Multiplication factor for each of anatomical anthropometric parameters of adolescents of age 16 in Addis Ababa, Ethiopia, 2019**

| Parameters | Male-50 | | | Female-53 | | |
|---|---|---|---|---|---|---|
| | Mean | MF | | Mean | MF | |
| | | Mean | SD | | Mean | SD |
| Arm span(CM) | 163.83 | .991 | .030 | 155.18 | 1.002 | .030 |
| Rt arm length(CM) | 75.96 | 2.137 | .056 | 72.06 | 2.159 | .076 |
| Lt arm length(CM) | 75.85 | 2.140 | .057 | 72.04 | 2.160 | .079 |
| Rttibial length(CM) | 39.66 | 4.100 | .160 | 37.65 | 4.137 | .187 |
| Lt tibial length(CM) | 39.71 | 4.100 | .160 | 37.70 | 4.137 | .187 |

MF-multiplication factor SD-Standard deviation

**Table-16: Correlation and regression models to estimate stature from anatomical anthropometric parameters of adolescents of age 16 in Addis Ababa, Ethiopia, 2019**

| Parameters | R | $R^2$ | Adjusted $R^2$ | SEE | Regression equation | sig. |
|---|---|---|---|---|---|---|
| Arm span(CM) | .857 | .735 | .732 | 4.269 | 40.34+0.743(AS) | .000 |
| Rt arm length(CM) | .849 | .721 | .718 | 4.378 | 40.52+1.599(RAL) | .000 |
| Lt arm length(CM) | .836 | .698 | .695 | 4.553 | 41.23+1.591(LAL) | .000 |
| Rttibial length(CM) | .835 | .698 | .695 | 4.557 | 65.43+2.416(RTL) | .000 |
| Lt tibial length(CM) | .831 | .691 | .688 | 4.610 | 65.12+2.421(LTL) | .000 |

### 5.8.3 Age specific Correlation, regression model and multiplication factor to estimate standing height from anatomical anthropometric parameters for adolescents of age 17

Age specific Pearson's correlation coefficient (R) and simple linear regression equations were formulated for each anatomical anthropometric measurement to estimate stature for study participants. All anatomical anthropometric parameters were significantly correlated with standing height of adolescents of age 16 with P<0.00(Table 18)

Age specific multiplication factor were also computed to estimate stature of adolescents of age 17.

**Table 17: Multiplication factor for each of anatomical anthropometric parameters of adolescents of age 17 in Addis Ababa, Ethiopia, 2019**

| Parameters | Male-52 | | | Female-54 | | |
|---|---|---|---|---|---|---|
| | Mean | MF | | Mean | MF | |
| | | Mean | SD | | Mean | SD |
| Arm span(CM) | 167.23 | .992 | .029 | 158.00 | .993 | .025 |
| Rt arm length(CM) | 77.42 | 2.145 | .087 | 73.64 | 2.131 | .071 |
| Lt arm length(CM) | 77.29 | 2.149 | .084 | 73.45 | 2.137 | .072 |
| Rttibial length(CM) | 40.90 | 4.066 | .209 | 38.55 | 4.080 | .224 |
| Lt tibial length(CM) | 41.11 | 4.066 | .209 | 38.56 | 4.080 | .224 |

MF-multiplication factor SD-Standard deviation

**Table 18: Correlation and regression model to estimate stature from anatomical anthropometric parameters of adolescents of age 17 in Addis Ababa, Ethiopia, 2019**

| Parameters | R | $R^2$ | Adjusted $R^2$ | SEE | Regression equation | sig. |
|---|---|---|---|---|---|---|
| Arm span(CM) | .841 | .708 | .705 | 4.269 | 29.05+0.814(AS) | .000 |
| Rt arm length(CM) | .747 | .557 | .553 | 5.251 | 54.47+1.415(RAL) | .000 |
| Lt arm length(CM) | .750 | .563 | .559 | 5.217 | 52.33+1.446(LAL) | .000 |
| Rttibial length(CM) | .660 | .435 | .430 | 5.933 | 88.46+1.834(RTL) | .000 |
| Lt tibial length(CM) | .664 | .441 | .436 | 5.900 | 88.05+1.840(LTL) | .000 |

### 5.8.4 Age specific Correlation, regression model and multiplication factor to estimate standing height from anatomical anthropometric parameters for adolescents of age 18

Age specific Pearson's correlation coefficient (R) and simple linear regression equations were formulated for each anatomical anthropometric parameter to estimate stature for adolescents of age 18. All anatomical anthropometric parameters were significantly correlated with standing height of adolescents of age 18 with $P<0.00$. Age specific multiplication factor were also computed to estimate stature of adolescents of age 18.

### Table 19: Multiplication factor for each of anatomical anthropometric parameters of adolescents of age 18 in Addis Ababa, Ethiopia, 2019

| Parameters | Male-51 | | | Female-54 | | |
|---|---|---|---|---|---|---|
| | Mean | MF | | Mean | MF | |
| | | Mean | SD | | Mean | SD |
| Arm span(CM) | 168.79 | .993 | .034 | 156.05 | 1.004 | .043 |
| Rt arm length(CM) | 78.48 | 2.136 | .078 | 72.16 | 2.172 | .099 |
| Lt arm length(CM) | 78.44 | 2.137 | .072 | 72.29 | 2.168 | .096 |
| Rttibial length(CM) | 40.65 | 4.133 | .240 | 37.84 | 4.144 | .184 |
| Lt tibial length(CM) | 40.83 | 4.133 | .240 | 38.00 | 4.144 | .184 |

MF-multiplication factor SD-Standard deviation

### Table-20: Correlation and regression models to estimate stature from anatomical anthropometric parameters of adolescents of age 18 in Addis Ababa, Ethiopia, 2019

| Parameters | R | $R^2$ | Adjusted $R^2$ | SEE | Regression equation | sig. |
|---|---|---|---|---|---|---|
| Arm span(CM) | .780 | .608 | .605 | 5.504 | 50.05+0.689(AS) | .000 |
| Rt arm length(CM) | .780 | .608 | .604 | 5.508 | 58.19+1.378(RAL) | .000 |
| Lt arm length(CM) | .798 | .637 | .633 | 5.300 | 53.65+1.438(LAL) | .000 |
| Rttibial length(CM) | .709 | .503 | .498 | 6.204 | 76.33+2.182(RTL) | .000 |
| Lt tibial length(CM) | .704 | .495 | .490 | 6.249 | 75.62+2.190(LTL) | .000 |

# 6. Discussions

The present study was designed to estimate stature from anatomical anthropometric measurements including arm span, arm length and tibial length among 416 adolescents of age 15-18 in Addis Ababa, Ethiopia.

The existence of sexual dimorphism of anatomical anthropometric parameters was evaluated in the study and the result showed that there was statistically significant difference in mean value of measurements. As illustrated in table 6 the mean value of height, weight and other anthropometric parameters except for BMI was significantly higher for male adolescents. So, the same regression equation cannot be used in both sexes to estimate stature from arm span, arm length and tibial length. The mean value of BMI was found to be significantly higher in female adolescents.

The results of this study are in line with the study conducted among Bengali children aged 3-11, the results of both studies showed that the mean value of height, arm span, arm length and tibial length in male participants was significantly higher(Dorjee et al., 2016).

In a research on Malawian children, higher mean stature and other anthropometric parameters of male participants were also shown (Zverev et al., 2005).

The above sexual dimorphism in stature and other anthropometric parameters is most commonly attributed to result from hormonal, environment and sex chromosome composition. Sex hormones such as estrogen and testosterone are highly relevant in closure of growth plates in the long bones and they also affect the secretion of other growth-related hormones such as growth hormone and insulin-like growth factor, therefore it is reasonable to hypothesize that the differential sex steroid patterns may contribute some part in sex difference in stature(Giles et al., 2001).

A number of studies have assessed the relationship between stature, arm span, arm length and tibial length and its importance in providing evidence that stature can be predicted from those anatomical anthropometric parameters in adolescents.(Mazicioglu et al., 2009, Yabanci et al., 2010, Dorjee et al., 2016). Result of the present study also showed that arm span, arm length, tibial length and weight of both sexes have statistically significant correlation with the stature ($p<0.05$).

Longer mean height than arm span among Addis Ababa adolescents of age 15-18 was recorded in the present study. This result is in agreement with the reports of Study done in Limpopo Province, South Africa.(Monyeki et al., 2016) and also Similar results were reported in a study done among for the four ethnic groups Oromo, Amhara, Tigre and Somali in Ethiopia (de Lucia et al., 2002).Moreover, shorter arm span compared with height was reported among Turkish children aged 7–14 years (Yabanci et al., 2010).

The finding of the present study was in disagreement with the finding of study conducted in Jimma, South West, Ethiopia among 660 study participants where arm span exceeded height in male participants,while arm span was less than height in female participants (Digssie et al., 2018). 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 current study, arm span was significantly correlated with stature in males ($R = 0.843$, $P < 0.05$) and in females ($R = 0.708$, $P <0.05$). Correlation between arm span and height was the strongest in both male and female study participants. And arm span was found to be the strongest predictor of the stature of adolescents of both sexes. This is in line with a study conducted in Turkey among adolescents of age 6–17 years.(Mazicioglu et al., 2009). The present study was also in agreement with study conducted in Jimma, South West, Ethiopia on 660 study participants (Digssie et al., 2018).

In the present study arm length was significantly correlated with stature in males (right arm length $R = 0.806$ and left arm length $R = 0.813$ and $P < 0.05$) and in female (right arm length $R = 0.635$ and left arm length $R = 0.636$ and $P < 0.05$). Arm length was found to be strong predictor of height next to arm span in both male and female study participants. This is in line with study conducted in Bengali Hindu on a total of 240 children of aged 3-11 (Dorjee et al., 2016).A number of other comparable studies reported similar findings with the present study.

In the current study tibial length was found to be significantly correlated with standing height in males (right tibial length $R = 0.738$ and left tibial length $R = 0.744$ and $P < 0.05$) and in female (right tibial length R = 0.611 and left tibial length R = 0.599 and $P < 0.05$).Tibial length was also found to be strong predictor of height in study conducted in Dharavi, India among 141 children with mixed disabilities and 162 non-disabled control children of age 2-6 years(Yousafzai et al., 2003). The correlation coefficient in the present was also similar with another study conducted on 400 subjects in the age group 17- 24years in India(Khatun et al., 2016).

Multiplication factor for male participants of the current study was 0.992, 2.143, 2.146, 4.086, and 4.073 for arm span, right arm length, left arm length, right tibial length and left tibial length respectively and multiplication factor for female was 0.999, 2.151, 2.153, 4.123 and 4.117 for arm span, right arm length, left arm length, right tibial length and left tibial length respectively. Similarly study done in Garo tribal Bangladesh on 100 participants the mean multiplication factor was found to be 0.999 (Hossain et al., 2011). Even though multiplication factor is easy to remember it is less accurate as compared with regression models to estimate standing height of an individual; the mean of estimated stature by multiplication factor was highly deviated as compared with estimated stature by linear regression formula. Previous studies done around the world like (Krishan et al., 2011,Wakode et al., 2015) also suggested regression formula is more precise to estimate stature than multiplication factor which is in line with current study.

This inconsistency may be explained by differences in age group, sample size and measuring instruments in this study and the current study.

The current study also formulated both simple linear and multiple linear regression formulas from arm span, arm length, and tibial length separately for both sexes. The accuracy of simple linear regression equations was assessed by using coefficient of determination ($R^2$) and standard error of estimate for each of anatomical anthropometric parameter. Result of the present study in table 9 indicated that $R^2$ value in male adolescents ranges 0.404 to 0.711 and standard error of estimate was ranges from 4.790 to 6.012. Regression equation with the highest value of $R^2$ and lowest value of SEE is relatively best estimator as compare with models with lower $R^2$ and higher SEE. The current studies indicated that the equation formulated by arm span had higher $R^2$ and lower SEE as compared with other anthropometric parameters. The results of the present study is in agreement with numerous studies like (Yousafzai et al., 2003,Zhu et al., 2015, Digssie et al., 2018), since they confirmed that arm span is best estimator of stature than arm length and tibial length.

In the present study multiple regression equation for combination of anthropometric parameters was found to be a better predictor of stature than any of single anatomical anthropometric parameters, as indicated in table 11, highest $R^2$ value of 0.764 and lowest SEE value of 4.347 for male participants was found for a regression model combining, arm span, right arm length and left tibial length. Similarly, table 12 indicates that highest $R^2$ value 0.551 and lowest SEE value of 3.960 for female study participants was found for a regression equation combining Arm span, left arm length and right tibial length. Similar results have been reported by(Krishan et al., 2011, Dorjee et al., 2016,) showed that presence of arm length and tibial length along with arm span showed increased predictive strength in the step-wise regression.

The present study also evaluates accuracy of estimated stature by comparing the mean values of estimated and actual stature and dependent student t- test was performed to justify the existence of mean difference for both sexes separately. The mean value of height estimated from arm span, arm length, and tibial length show statistically insignificant difference (P value > 0.05) when compared with mean value of stature of study participants. The findings of the present study were found to be in agreement with numerous studies like(Hossain et al., 2011 , Dorjee et al., 2016,Kamal et al., 2016, Digssie et al., 2018)where student t-test was computed and the result indicate that there is no statistically significant mean difference between actual and estimated height.

# 7 Conclusion

Stature has showed statistically significant correlation with arm span, arm length and tibial length in both sexes.

Arm span highly correlates with height and regression equations fitted from arm span was found to be best estimator of height among adolescents of age 15-18 in both sexes.

Over all mean value of stature, arm span, arm length and tibial length were significantly higher in male adolescents than their female counter parts.

There was statistically significant mean difference for all anatomical anthropometric parameters between adolescents of different age.

There is statistically insignificant difference between right and left arm length and tibial length in both male and female study participants.

Simple linear and multiple regression models were formulated from each anatomical anthropometric parameter to predict stature of an individual. And the strength of prediction in general increased with the increasing number of anatomical anthropometric parameter and from linear to stepwise multiple regressions.

There was no statistically significant mean difference between estimated and actual stature in both male and female study participants.

Generally, arm span, arm length and tibial length can be used as a good predictor of stature when difficulty arose in linear measurement of height, in case of mass disasters and for forensic investigations purposes.

# 8 Limitation of the study

Lack of literature on estimation of stature from arm span, arm length and tibial length on adolescents of age below 18 becomes challenging to compare the finding of the present study with national investigators.

Refusal of some students to participate in the study due to physical discomfort of taking measurements.

# 9 Recommendation

Large scale similar researches should be conducted on adolescents of age below 18 which are expected to represent participants from different geographical areas and different age groups and nationwide guideline should be developed to estimate stature from arm span, arm length and tibial length.

It is recommended to carry on further detailed studies on other body parameters to estimate stature on adolescents of age below 18.

It is recommended to conduct further detailed studies to investigate the reasons for bilateral asymmetry of anatomical anthropometric parameters on adolescents of age below 18.

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# Annex

## Annex 1: Informed Consent Form (English version)

Addis Ababa University, College of Health Science

Subject Information Sheet

Hello,

My name is_____________________________ I am here on behalf of Bereket Sisay, a student in Addis Ababa University, College of Health Science, and Department of Human Anatomy. I am conducting a research on ***"Estimation of stature from arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia."*.** I have received permission from Addis Ababa University, College of Health Science and the respected sub city education bureau to conduct this study.

You are selected by multistage random sampling technique to participate in this study because you are currently attending in one of those selected general secondary schools for the study purpose. Your participation in this study is totally based on your willingness. You have the right to choose not to take part in this study. If you choose to take part, you have also the right to stop or withdraw at any time of the study.

If you agree to participate in this study, your height, arm span, arm length and tibial length will be measured. You will also be interviewed about background information. You can stop at any time if you don't feel comfortable during an interview and measurement process. The measurement and filling the questionnaire will take about 20 minutes.

### Informed Consent and/or Ascent Form

Based on the understanding of the above information, are you willing to participate in this study?

A) Yes

B) No

If yes, I will continue and

If no, I will skip to next participant

**Thank you for your kind cooperation**

Data collector

Name_________________________________ Signature_______________

Questionnaires ID number____________________

Date of data collected__________________

Result of data collected

A) Completed

B) Not completed

C) Partially completed

D) Refused

Checked by Supervisor: Name _______________________Signature____________

For further explanation, use the Principal Investigator's Address;

Name: Bereket Sisay G/Michael

Email: *bereket.sisay@yahoo.com*

Cell phone:  +251 916810489

## Annex 2: Questionnaire (English Version)

### Part I. Socio-demographic Variables

| S/N | Questions | Alternative response |
|---|---|---|
| 1.1 | Sex | 1. Male 2. Female |
| 1.2 | Age in full years | ----------years |
| 1.3 | What grade are you now? | -------------- |
| 1.4 | School type? | 1.Private/ /community/ missionary<br>2.Government./public |
| 1.5 | Religion | 1.Orthodox Christian 2.Muslim 3.Protestant<br>4.Catholic 5.Other specify________ |
| 1.6 | In which region you spent most of your age? | 1. Addis Ababa 2.Amhara 3.Oromiya 4.Tigray<br>5.Gambela 6.SNNP 7.Somali 8.B/Gumuz<br>9.Hareri 10.Afar |
| 1.7 | Family size | 1.≤5<br>2.>5 |
| 1.8 | Do you have long standing illness | 1.Yes<br>2. No |

## Part II. Anthropometric indices cheek list

| No | Anthropometric indices | Equipment | Result |
|---|---|---|---|
| 2.1 | Height (Centimeters) | Stadiometer | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement. ☐ ☐ ☐ ☐ |
| 2.2 | Weight (Kilogram) | Mechanical balance | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement ☐ ☐ ☐ ☐ |
| 2.3 | Arm span(centimeters) | Non-elastic tape meter | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement. ☐ ☐ ☐ ☐ |
| 2.4 | Arm length(centimeters) (RIGHT SIDE) | Non-elastic tape meter | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement ☐ ☐ ☐ ☐ |
| 2.5 | Arm length(centimeters) (LEFT SIDE) | Non-elastic tape meter | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement. ☐ ☐ ☐ ☐ |
| 2.6 | Tibial length(centimeters) (RIGHT SIDE) | Non-elastic tape meter | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement ☐ ☐ ☐ ☐ |
| 2.7 | Tibial length(centimeters) (LEFT SIDE) | Non-elastic tape meter | 1st measurement. ☐ ☐ ☐ ☐ |
| | | | 2nd measurement ☐ ☐ ☐ ☐ |

## Annex 3: Figures showing measurement of weight, stature and anatomical anthropometric parameters

**Figure 9: Measuring standing height of adolescents of age15-18 in Addis Ababa, Ethiopia,2019**

**Figure 10: Measuring weight of adolescents of age 15-18 in Addis Ababa, Ethiopia,2019**


**Figure 11: Measuring arm span of female adolescents of age15-18 in Addis Ababa, Ethiopia, 2019**

Figure 12: Measuring arm span of male adolescents of age 15-18 in Addis Ababa, Ethiopia,2019

**Figure 13: Measuring arm length of female (right) and male(left) adolescents of age 15-18 in Addis Ababa, Ethiopia, 2019**