

**ORIGINAL ARTICLE****Estimation of Stature from Arm Span, Arm Length and Tibial Length among Adolescents of Aged 15-18 in Addis Ababa, Ethiopia****Abay Mulu<sup>1\*</sup>, Bereket Sisay<sup>2</sup>****OPEN ACCESS**

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**ABSTRACT**

**BACKGROUND:** *Knowing the relationship between stature and different anatomical anthropometric parameters help forensic scientists, anatomists and clinicians to estimate standing height from mutilated remains of body parts in clinical practices and forensic investigations. It is a necessity when measuring height is unenviable due to certain medical conditions and in field studies. This study aims to estimate stature from arm span, arm length and tibial length among adolescents of age 15-18 in Ethiopia.*

**METHODS:** *A school based cross-sectional study was carried out among 416 high school students in Addis Ababa, Ethiopia 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 Statistical Package for Social Sciences version 23. Regression models and multiplication factors were generated for estimation of height from anthropometric parameters.*

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

**CONCLUSION:** *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*

**INTRODUCTION**

Stature is the highest distance measured from the point where the heel touches the floor to the vertex of the head while the person is erect (1). 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 during forensic investigations. From all of the above variables stature is the most vital tool for personal identification in case when only remains of a human body found (2).

Even though standing height plays a big role in personal identification of an individual in case of medico-legal scenario and in many clinical conditions, there are conditions which hinder the direct measurement of standing height like spinal and limb deformities, amputations, fractures, scoliosis, paralysis and pain, in this cases segment of the body are used for estimating the standing height of an individual (3).

Moreover, problems and difficulties in measurement of height can be encountered in field studies compared with clinical settings because of the portability, accessibility, and expense of specialized equipment used for measurement of height. Therefore, surrogate measures of height that can be obtained by simple and portable tools are mandatory. Therefore, most regression formulas derived are meant to be specific for a particular region and can be used only in that particular area of study and for that particular age group in which the study was conducted. It is indeed, necessary to derive regression equations, which are age group, gender, ethnic, and geographic area specific (3,4). As my search has shown there is no study done in Ethiopian adolescents of age below 18 on estimation of stature from arm span, arm length and tibial length, so this study aims to estimate stature from arm span, arm length and tibial length among adolescents of age 15-18 in Addis Ababa, Ethiopia.

## MATERIALS AND METHODS

**Study setting and study population:** School based descriptive cross-sectional study was carried out among 416 study participants of age 15-18 from selected public and private general secondary schools in Addis Ababa, Ethiopia. The study was conducted from May to June 2019. The sample size for the study was determined based on formula for single population proportion, using, level of

significance as 95%, ( $Z_{\alpha/2}=1.96$ ), margin of error 5 and proportion of 0.5.

Multi-stage sampling method was used to select samples that fulfil inclusion criteria. A total of 15 schools, (10 non-governmental and 5 governmental) schools were selected randomly. And the study subjects were selected from selected sections by systematic random sampling technique using student list of the class.

**Data collection and instrument:** The data were collected through structured, pretested interviewer-administered questionnaire and anthropometric parameters were taken by direct measurements. According to Marfell-Jones (5), the anthropometric measurements were taken using the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). Length was measured by using non-elastic tape meter.

Stature was measured using a portable stadiometer and put to the nearest point two decimal places of centimeters. Weight was also measured with standard mechanical balance and recorded to the nearest 0.1kg.

Arm span measurements were taken from the tip of the middle finger of one arm to the tip of the middle finger of the other arm (dactylion to dactylion) with the arms outstretched at right angles of  $180^{\circ}$  to the body and with extended elbow and wrist, and the palms facing directly forward.

Arm length was taken from the tip of humerus (acromion) bone to tip of the middle finger (dactylion) of right arm while arm hanging down wards lateral to the body. Tibial length was measured from the medial most superficial point on upper border of medial condyle of tibia and tip of medial malleolus of right leg.

All the anthropometric measurements except for weight were measured when the subjects were standing in the Frankfort horizontal plane.

**Data analysis and processing:** Data were edited, coded, and entered into Epi-Data version 4.4.3.1 and were exported for analyses to SPSS for windows version 23. Statistical significance was set at  $p<0.05$ . Simple and multiple linear regression models and multiplication factors were generated to estimate stature of study

participants from arm span, arm length and tibial length.

Before conducting analysis of the present data several tests for basic assumptions of linear regression like tests of linearity, tests of homoscedasticity and tests of normality; and reliability analysis were taken into consideration.

Reliability of the present data was assessed by computing Cronbach's Alpha. In the present study 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.

**RESULTS**

A summary of the anthropometric measurements in both sexes is shown in Table 1. The mean of the height and arm span for male subjects was 164.36±8.89cm and 165.7±9.46cm, respectively. And for female subjects it was 155.74±5.86cm and 155.96±6.95cm. Independent sample t-test was generated to assess the presence of sexual dimorphism between Height and Arm span and the result illustrates that there was statistically significant higher mean for male study subjects than their female counter parts (body height: t=11.714; p<.000, and arm span: t=12.001; p<.000).

The mean of the arm length and tibial length for male subjects was 76.74±4.67cm and 40.31±2.91cm, respectively. And for female

subjects it was 72.49±3.48cm and 37.85±2.26cm. Independent sample t-test was also generated to assess the presence of sexual dimorphism between arm length and tibial length and the result illustrates that there was statistically significant higher mean for male study subjects than the females (Arm length: t=10.547; p<.000, and Tibial length: t=9.623; p<.000). Moreover, it was also observed that most 60.4% of male and 55.1% of female adolescents have higher measurement of height than arm span as shown in Table 2.

Table 1: Anthropometric measurements of study subjects.

| Variable             | Measurements |             |
|----------------------|--------------|-------------|
|                      | Range        | Mean ± SD   |
| <b>Body height</b>   |              |             |
| Male                 | 136.5-192.0  | 164.36±8.89 |
| Female               | 143.0-176.0  | 155.74±5.86 |
| <b>Arm Length</b>    |              |             |
| Male                 | 64.2-88.90   | 76.74±4.67  |
| Female               | 63.1-82.0    | 72.49±3.48  |
| <b>Arm Span</b>      |              |             |
| Male                 | 131.5-186.1  | 165.7±9.46  |
| Female               | 136.2-172.5  | 155.96±6.95 |
| <b>Tibial Length</b> |              |             |
| Male                 | 32.1-47.3    | 40.31±2.91  |
| Female               | 31.9-44.7    | 37.85±2.26  |

SD-Standard Deviation

Table 2: 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%)  |

**Correlation between standing height and anatomical anthropometric parameters:** The simple correlation coefficient and their 95% confidence interval analysis between the anthropometric measurements are presented in Table 3. The relationships between body height and anatomical anthropometric parameters were

high and significant in study subjects regardless of sex. Arm span was found to be highly correlated with stature in both sexes. The mean value of multiplication factors for each anatomical anthropometric parameters of male and female study subjects is illustrated in Table 4.

Table 3: Correlation of height with anatomical anthropometric parameters of male and female participants in Addis Ababa, Ethiopia.

| Variable             | Correlation coefficient | 95% confidence interval | Significant p-value |
|----------------------|-------------------------|-------------------------|---------------------|
| <b>Arm span</b>      |                         |                         |                     |
| Male                 | 0.843                   | 0.842-0.844             | 0.000               |
| Female               | 0.708                   | 0.705-0.710             | 0.000               |
| <b>Arm length</b>    |                         |                         |                     |
| Male                 | 0.806                   | 0.805-0.807             | 0.000               |
| Female               | 0.635                   | 0.630-0.638             | 0.000               |
| <b>Tibial length</b> |                         |                         |                     |
| Male                 | 0.738                   | 0.734-0.740             | 0.000               |
| Female               | 0.611                   | 0.608-0.615             | 0.000               |

Table 4: Multiplication factor for each anatomical anthropometric parameter of male and female study participants in Addis Ababa, Ethiopia.

| Subject | Arm span         | Arm length        | Tibial length     |
|---------|------------------|-------------------|-------------------|
|         | MF mean $\pm$ SD | MF mean $\pm$ SD  | MF mean $\pm$ SD  |
| Male    | 0.992 $\pm$ 0.30 | 2.143 $\pm$ 0.077 | 4.086 $\pm$ 0.201 |
| Female  | 0.999 $\pm$ 0.32 | 2.151 $\pm$ 0.082 | 4.123 $\pm$ 0.194 |

MF-Multiplication Factor, SD-Standard Deviation

**Simple linear regression equations to estimate of stature from anatomical anthropometric parameters for male and female study participants:** A summary of regression results for male and female study subjects is provided in the Table 5 below. The high values of the

regression coefficient (coefficient of determination) signify that all anatomical anthropometric parameters especially that of arm span significantly predicts body height in both sexes.

Table 5: Estimation of stature from anatomical anthropometric parameters for male and female study participants in Addis Ababa, Ethiopia.

| Variable             | Regression coefficient(R <sup>2</sup> ) | SEE   | Regression equation | p-value |
|----------------------|---|-------|---------------------|---------|
| <b>Arm span</b>      |   |       |                     |         |
| Male                 | 0.711                                   | 4.790 | 33.11+0.792(AS)     | .000    |
| Female               | 0.501                                   | 4.153 | 62.59+0.597(AS)     | .000    |
| <b>Arm length</b>    |   |       |                     |         |
| Male                 | 0.649                                   | 5.280 | 46.71+1.53(AL)      | .000    |
| Female               | 0.403                                   | 4.546 | 78.36+1.06(AL)      | .000    |
| <b>Tibial length</b> |   |       |                     |         |
| Male                 | 0.545                                   | 6.012 | 73.53+2.25(TL)      | .000    |
| Female               | 0.373                                   | 4.654 | 95.96+1.58(TL)      | .000    |

SEE- Standard Error of Estimate, AS- Arm Span, AL- Arm Length TL- Tibial Length

**Step wise multiple linear regression including bilateral and different anatomical anthropometric parameters:** On multivariable linear regression analyses, arm span and arm

length, arm span and tibial length, tibial length and arm length, and arm span, arm length and tibial length significantly predicted standing height measurement ( $p < 0.05$ ) (Table 6).

Table 6: Step-wise multiple linear regression for estimation of stature from bilateral and different anthropometric parameters for study participants in Addis Ababa, Ethiopia.

| Parameter     | Regression coefficient(R <sup>2</sup> ) | SEE   | Dublin Watson | Regression equation              | P-value |
|---------------|---|-------|---------------|----------------------------------|---------|
| <b>Male</b>   |   |       |               |                                  |         |
| AS-AL         | 0.726                                   | 4.670 | 1.924         | 31.05+0.56(AS)+0.50(AL)          | 0.000   |
| AS-TL         | 0.756                                   | 4.413 | 1.745         | 28.71+0.6(AS)+0.89(TL)           | 0.000   |
| AL-TL         | 0.710                                   | 4.815 | 1.995         | 40.22+1.04(AS)+1.06(TL)          | 0.000   |
| AS-AL-TL      | 0.764                                   | 4.347 | 1.866         | 27.97+0.49(AS)+0.27(AL)+0.85(TL) | 0.000   |
| <b>Female</b> |   |       |               |                                  |         |
| AS-AL         | 0.507                                   | 4.139 | 1.846         | 60.97+0.5(AS)+0.23(AL)           | 0.000   |
| AS-TL         | 0.549                                   | 3.961 | 1.883         | 58.12+0.45(AS)+0.70(TL)          | 0.000   |
| AL-TL         | 0.486                                   | 4.225 | 1.808         | 68.38+0.72(AL)+0.92(TL)          | 0.000   |
| AS-AL-TL      | 0.551                                   | 3.960 | 1.854         | 56.95+0.39(AS)+0.15(AL)+0.68(TL) | 0.000   |

SEE- Standard, Error of Estimate, AS- Arm Span, AL- Arm Length, TL- Tibial Length

## DISCUSSION

Age and sex along with stature constitute the important parameters for establishing the identity of the remains of the human body in case of forensic investigation (6).

The mean differences of stature, arm span, arm length and tibial length among Addis Ababa male and female study subjects of the present study showed statistically significant difference ( $p \sim 0.00$ ). This is in line with studies like (7-9). However, some studies indicated that there is no significant mean difference of anthropometric parameters between sexes (10).

The estimation of stature using various anthropometric measurements are quite the age-old investigations over the past centuries and it has been attempted by many authors in many countries. As it is already mentioned, all of them estimated stature from various anatomical anthropometric measurements, but it is important to emphasize that the arm span has been derived the most reliable parameter for predicting body height of an individual (11).

In the study conducted by Steele and Chenier (12), the arm span was nearly 8.3cm more than the body height for black population,

whereas for white population this difference was only 3.3cm (11). They have noted in their study done on South Indian females, the arm span was nearly 2.5cm higher than stature. In study (13), arm span was 5.8cm more than body height for

Nigerian males whereas, for Nigerian females, this difference was only 4cm which is similar to that noted in the white population although they are black. The findings of the above studies contradict with the result of the present study where 60.4% of male and 55.1% of female study participants have higher mean value of height than arm span, while only 38.1% of male and 39.3% of females have higher arm span.

The results of many studies conducted across the globe indicated that arm span and height showed the highest correlation coefficient than any other anthropometric measurements. For example, a study (11) reported that the correlation coefficient was  $R=0.82$ , while in another study (8) correlation was  $R=0.87$  for males and  $R=0.81$  for the female population. In the most recent studies, (13) reported that correlation was  $R=0.83$ , while others (14) reported that the correlation was  $R=0.861$  for males and  $R=0.809$  for female study subjects.

The findings from the present study was found to be in line with the findings of the above study where arm span showed the highest value of correlation than any other anthropometric parameters for both sexes ( $R=0.843$  for males and  $R=0.708$  for females). Arm length also has shown to be strongly associated with stature in the present study with correlation coefficient ( $R$ ) of  $0.806$  for male and  $0.635$  for female study subjects; this is in line with studies done by Dorjee et al. (10).

Tibial length is strongly associated with stature in the present study with correlation coefficient ( $R$ ) of  $0.738$  for male and  $0.611$  for female study subjects, this is also in line with numerous studies (10,15,16).

**Choosing the best regression equation for stature estimation:** The study of many researchers (17-20) reported that the best stature predictor to be arm span followed by those models containing arm length and then tibial length. In the present study it was evident that simple linear regression equations derived from arm span was found to be the best predictor of standing height with the largest value of regression coefficient  $R^2=0.711$  for male and  $R^2=0.501$  for female study participants, followed by regression equations derived from arm length and tibial length respectively.

However, it was evident that in the present study step wise multiple linear regression equation consisting arm span, arm length and tibial length were found to be the best predictor of stature than any other equation consisting one or two parameters in both sexes. This is in line with numerous studies conducted in different areas and in different study set up (2,21,4).

In the present study height prediction equation using arm span, a centimeter increase in arm span increased height by  $0.792\text{cm}$  in male and  $0.597\text{cm}$  in female study subjects with  $p<0.001$ . Thus, height can be predicted from arm span as: Height =  $33.11+0.792$  (Arm span) in male and Height =  $62.59+0.597$  (Arm span) in female.

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 ( $p>0.05$ ) when compared with mean value of stature of study participants. The findings of the present study is in agreement with numerous studies like (22,23,4) where student t-test was computed and the results indicate that there is no statistically significant mean difference between actual and estimated heights.

In 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. The strength of prediction of regression equations in general increased with 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.

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