PREDICTION OF HEIGHT FROM ARM SPAN, HALF ARM SPAN AND KNEE HEIGHT AMONG ETHIOPIAN ADULTS IN JIMMA UNIVERSITY, ETHIOPIA

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A THESIS SUBMITTED TO DEPARTMENT OF POPULATION AND FAMILY HEALTH, COLLEGE OF HEALTH SCIENCES, JIMMA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTERS OF SCIENCE IN HUMAN NUTRITION

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Abstract

Introduction: Human height or stature is the distance from the bottom of the feet to the top of the head while the person is standing erect. Standing height measurements in older people, bed ridden patients and peoples with skeletal deformity can be difficult to obtain due to different reasons. Alternative height measurements such as arm span, knee height, and half arm span have been shown to be useful surrogate measures of stature in older people, bed ridden patients and peoples with skeletal deformity. However, their ability to predict height could differ across populations and this has not been reported in Ethiopia.

Objective: The aim of this study is to develop formula that predicts height from arm span, half arm span and knee height and assess its agreement with measured height.

Methods: A cross sectional study was conducted from March 15 to April 21, 2016 in Jimma University assessing among a total of 660 (330 females and 330 males) subjects aged 18-40 years. A two-stage sampling procedure was employed to select study participants. Data were collected using interviewer administered questionnaire and anthropometric measurements. Data were edited and entered into EpiData version 3.1 and statistical analyses were done using SPSS for windows version 20. Linear regression was fitted to predict height from the independent variables. Bland-Altman analysis was employed to see the agreement between actual height and predicted heights. $P< 0.05$ was used to declare as statistically significance.

Results: Multivariable linear regression analyses showed that arm span (β =0.63, $P<0.001$, R^2=87%), half arm span (β=1.05, $P<0.001$, R^2=83%) and knee height (β=1.62, $P<0.001$, R^2=84%) are important predictors of height. The Bland-Altman analyses showed good agreement between measured height and predicted height.

Conclusion: Height can be predicted from arm span, half arm span and knee height when measuring standing height is not possible. Arm span was found to be the best predictor of height. These equations can be used to assess the nutritional status of bed ridden patients, peoples with disability and elderly population in Ethiopia.

Key words: Height, Arm Span, Half arm Span, Knee Height

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Table of Contents

Abstract I

Acknowledgments II

List of tables V

List of figures VI

Acronyms and abbreviations VII

1. Introduction 1

1.1. Background 1

1.2. Statement of the problem 2

2. Literature review 4

3. Significance of the study 8

4. Objectives 9

4.1. General objective 9

4.2. Specific objectives 9

5. Methods and participants 10

5.1. Study area and period 10

5.2. Study design 10

5.3. Population 10

5.3.1. Source population 10

5.3.2. Study population 10

5.4. Inclusion and exclusion criteria 10

5.5. Sample size determination and sampling procedure 11

5.6. Study variables 12

5.7. Data collection 12

5.8. Data quality control 13

5.9. Data Processing and Analysis 13
5.10. Definitions of Terms 14
5.11. Ethical consideration 14
5.12. Dissemination plan 14
6. Result 15
6.1. Characteristics of Study Participants 15
6.2. Anthropometric Measurements of Study Participants 16
6.3. Prediction of Height from Arm Span, Half Arm Span and Knee Height 17
6.4. The Agreement between Measured Height and Predicted Heights 19
7. Discussion 22
8. Conclusion and Recommendations 25
8.1. Conclusion 25
8.2. Recommendations 25
9. References 26
Annex one: Questionnaire 30

List of Tables

Table 1: Region of study participants by sex among Ethiopian adults in Jimma University, March 2016. 15
Table 2: Ethnicity of study participants by sex among Ethiopian adults in Jimma University, March 2016. 16
Table 3: Mean (SD) anthropometric measurements of study participants in Jimma University, March 2016. 17
Table 4: The correlation of arm span, half arm span and knee height measurements with height among Ethiopian adults in Jimma University, March 2016. 17
Table 5: Prediction of height from arm spa, half arm span and knee height in Ethiopian adults in Jimma University, March 2016..... 19
Table 6: Bland-Altman analyses of measured and predicted height among Ethiopian adults in Jimma University, March 2016..... 20

List of Figures

Figure 1 Schematic presentation of sampling procedure 11
Figure 2: Bland-Altman plot of measured height and predicted height from arm span among Ethiopian adults in Jimma University, March 2016. 20
Figure 3 Bland-Altman plot of measured height and predicted height from half arm span among Ethiopian adults in Jimma University, March 2016. 21
Figure 4: Bland-Altman plot of measured height and predicted height from knee height among Ethiopian adults in Jimma University, March 2016. 21

Abbreviations

AS	Arm Span
BMI	Body Mass Index
BMR	Basal Metabolic Rate
CM	Centimeter
CSA	Central Statistics Agency
DS	Demi Span
DSEH	Demi-Span Equivalent Height
ENA	Emergency Nutrition Assessment
HSTP	Health Sector Transformation plan
KH	Knee Height
S	Stature
SDG	Sustainable Development goal
SEE	Standard error of estimate

1. Introduction

1.1. Background

Human height is defined as the vertical distance from the heels to the vertex in a subject standing erect. It is measured using a Stadiometer, usually in centimeters when using the metric system, and feet and inches the imperial system (1).

Measurement of body height is required to calculate body mass index, determination of basic energy requirements, standardization of measures of physical capacity and adjusting drug dosage, evaluation of children's growth, prediction and standardization of physiological variables such as lung volumes, muscle strength, glomerular filtration and metabolic rate (2,3).

Standing height is measured using a stadiometer on barefooted subjects, with their heels together and the heels, buttocks and back touching the stadiometer. The angles of both mandibles are then cupped and gentle upward traction applied till the lower orbital margin is level with the external auditory meatus (Frankfurt plane). A horizontal rigid sliding ruler is used to read the height directly from the scale on the stadiometer(4).

Standing height measurements in older people and people with skeletal deformity can be difficult to obtain due to an inability to stand straight or steadily due to pain, weakness, disability, or spinal deformities such as kyphosis or scoliosis (curvature of the spine) or due to osteoporosis. Therefore, height measurements in some older people and in people with skeletal deformity can be impossible or inaccurate and may not necessarily reflect their maximum attained height. Alternative height measurements such as arm-span, knee height , and half arm span have been shown to be useful surrogate measures of stature in older people and people with skeletal deformity, may be more accurate because the length of long bones, i.e. those in arms and legs, do not change with age, unlike vertebral height (5).

This study concerned with development of equation to determine height in a situation when there is difficulty of measuring accurate height according to the standard measurement of standing height or stature for the Ethiopian population.

1.2. Statement of the problem

Ageing of the population is the most important demographic change facing many countries around the world (6). With the growing number of elderly people, chronic diseases and disability become a public health challenge especially in developing countries, where the health care sector is less developed and suffering from limited resources. Moreover, the elderly population in developing countries is growing more rapidly than in more developed nations and it is projected that in 2020, 70% of those aged above 55 year will live in developing countries (7).

There were major change in population structures and disease pattern in the last century. The proportion of elderly people in the population is increasing due to the "demographic transition" which describes the shift from high fertility and high mortality to low fertility and low mortality. The "epidemiological transition" describes the change from a predominance of infectious disease, with high maternal and child mortality to a predominance of chronic disease (8)`.

Nutrition is an important determinant of health in elderly patients (9). Older persons are particularly vulnerable to malnutrition (10). Now a day, high obesity rates are a particular concern in urban areas in low-income country settings, while rural areas are often less affected speculate that better living conditions, access to energy denser diets and less physical activity might explain higher prevalence of overweight in urban compared to rural areas(11).

Elderly residents in nursing homes are at an increased risk of malnutrition due to a variety of factors including sensory loss, chewing and swallowing problems, a decrease in or loss of appetite, mobility restrictions, cognitive impairment, depressed mood and acute or chronic diseases demanding the use of multiple medications(12).

To manage nutritional problems, assessment of nutritional status is the first step. Anthropometric assessment is usually very informative and easy to use. Determining an individual's height accurately is important because height is a crucial factor for predicting essential nutritional status indicators, including body mass index (BMI), basal metabolic rate and body composition(13).

In older people, there is a loss of height with aging, as well as inaccuracies in obtaining height measurement because of spinal deformities such as kyphosis and scoliosis (14). As alternative height can be predicted from measurements such as arm span, knee height and half arm span have been used in some epidemiological studies in older people. Bed ridden patients and in people with skeletal deformity in whom a standing height measurement is not possible (15).

In the study conducted in Swedish elderly population indicated that there was age related misclassification of under nutrition and obesity attributed by inaccurate height estimation among the elderly. Under nutrition prevalence in men and women were 3.9 and 8.6% by knee height (KH), compared with 2.4 and 5.4% by standard BMI, and more pronounced for all women aged 85+ years (21% vs. 11.3%). The corresponding value in women aged 85+ years by demi span was 16.5% vs 10% by standard BMI. Obesity prevalence in men and women were 17.5 and 14.6% by KH, compared with 19.0 and 20.03% by standard BMI. Values among women aged 85+ years were 3.7% vs 10.4% by KH and 6.5% vs 12.7% by demi span compared with the standard (16).

Although there are many suggested formulas for height prediction with selected anthropometric measurements such as ulnar length, knee height, hand dimension, demi span, half arm span and arm span, an inaccurate prediction may occur due to the relationship between the anthropometric measurement and height depending on race, sex and age (17).

Individual and ethnic variations in respect of body height and its relation with arm span have been reported in European (18) and African populations (19). It has been also indicated that the estimating equation varies from race to race, and ethnic group to ethnic group (20).

This study intended to develop formula to predict height from arm span, half arm span and knee height among Ethiopian adults in Jimma University, Ethiopia.

2. Literature Review

In the study conducted in north India showed that Arm span exceeded height in 82.6% subjects. Mean height to arm span ratio was 0.97 and 0.98 in males and females, respectively, and was not significantly correlated with age. Linear regression equations were generated for both sexes for prediction of height from arm span and age. The use of height to arm span ratio was found to be a less suitable method than the use of regression equations in estimating height from arm span with linear regression model goodness of fit (R^2=0.82) (21).

Research conducted on Garo Tribal Bangladeshi females showed that the mean (± SD) of the stature was found 152.79 ± 5.62 cm and arm span was 154.74 ± 5.69. In more than 75% of the subjects, the arm span was between 152.00 and 166.99 cm. The arm span showed significant positive correlation (r=0.89) with the stature (22).

Study done in Serbian adults showed that the mean of the arm span for male subjects was 184.78±8.41 cm, which was 2.82±4.89 cm more than the body height and statistically significant, and for female subjects it was 164.67±8.09 cm, which was 2.15±4.68 cm less than the body height and statistically insignificant. The sex difference between body height and arm span measurements was statistically significant. Regarding linear regression model goodness of fit (R^2=0.66 for males and R^2=0.675 for females) (23)

Study done in Bosnian and Herzegovinian Adults showed that the mean of the arm span for male subjects was 184.50±8.27 centimeters, which was 0.73±1.17 centimeters more than the body height and statistically insignificant and for female subjects it was 169.85±8.01 centimeters, which was 1.97±1.45 centimeters less than the body height and statistically insignificant. The gender difference between body height and arm span measurements was statistically significant (body height and arm span; correlation coefficient was determined and it was 0.88 in male subjects and 0.88 in female subjects. Concerning linear regression model goodness of fit (R^2=0.767 for males and R^2=0.787 for females) (24).

A Study done Alva's Education Foundation showed that mean height for girls 157.38 (SD =6.96) cm and for boys 167.93 (SD=6.98) cm. Mean arm span for girls 161.63 cm and for boys 176.2 cm. The correlation coefficient between height and arm span was 0.89 for girls

and 0.83 for boys, which is significant for both groups. Correlation is significant at the 0.01 level. Height and arm span have strong correlation and arm span can be used as reliable parameter for predicting the height of young adult individuals (25).

Study conducted in Burgunji area of Nepal indicated that the mean of the arm span and body height of male subjects was found to be approximately equal (mean height with SD 167.39±6.17 and mean arm span with SD 168.01±7.65) and for female subject the arm span was greater than body height (mean height with SD 155.61±6.89 and mean arm span with SD 159.25±6.36). The simple correlation coefficient was determined and was statistically significant (male r= 0.682 and female r= 0.507). Concerning linear regression model goodness of fit (R^2= 0.75 for males and R^2=0.68 for females) (26).

The study conducted on Chakma Tribal Tripuri females indicated that the mean normal value of the arm span was 148.74± 5.34 cm and the stature was 149.26±5.82cm. The multiplication factor was estimated for the same hand measurements with the stature. Significant positive correlation was found in case of arm span with the stature (r =0.89) (27).

Study done on Thai population, anthropometric parameters with demi span, sitting height, knee height and combination were applied for height prediction in the adult Thai population. Although knee height had the highest precision as a single predictive parameter others parameters were also proposed with acceptable error. A combination of double and triple model might decrease actual deviation only in younger people. However, overestimation might be a concern in shorter people and vice versa in taller people (28).

In the research conducted on populations of northern India showed that the mean ± SD of height was (168.14±7.71 in males, 157.68±7.07 in females and 162.91±9.06 in both sexes) and knee height was (51.6±3.21 in males, 47.7±2.26 in females and 49.6±3.40in both sexes). correlation coefficients (r) values between body height and knee height was found to be statistically significant and positive in both males, females and in combined data with correlation coefficient of 0.75 in males, 0.51 in females and 0.78 in both sexes. Regarding linear regression model goodness of fit (R^2=0.6) and (adjustedR^2=0.06) (29).

Study done on Medical Students of Maharashtra, India showed that stature of males was 170.75 (±9.43) cm, and it was more than female 159.46 (±7.66) cm with statistical significance. Similarly, arm span of male was more than female and also found that correlation coefficient (r) of arm span and stature was 0.89 in males and 0.90 in females. Regression equation for estimation of stature from arm span was developed as follows, in males was height = 31.25 + 0.80 arm span and in females was height = 33.54 + 0.77 arm span with linear regression model goodness of fit (R^2=0.79 for males and R^2= 0.81 for females) (30).

A study conducted in Gujarat region showed that the mean and standard deviations of height and arm span (male height 175.95±5.92, female height 161.11 ± 5.62, male arm span 178.18 ± 7.08 and female arm span 162.31 ± 6.57). The correlation between stature and arm span was found to be 0.93 in total subjects, 0.81 in males and 0.87 in females (31).

A cross sectional study conducted in Thai adult women showed that measured heights showed a significant strongly positive correlation with the mean knee height (r=0.84). Mean knee height in a regression model exhibited the most accurate height prediction (adjusted R2 = 0.718, standard error of estimate =2.80), according to the equation "Height = 38.101 + 2.452 (average knee height) - 0.051(age)"(32).

A Cross sectional study conducted in Malaysia determined the height prediction equation from demi-span as follows: Men: Height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age) + 4.13; Women: Height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age). Height predicted from these new equations demonstrated good agreement with measured height and no significant differences were found between the mean values of predicted and measured heights in either gender (33).

A study conducted on South Indian women determines the height prediction formula from arm span with linear regression model goodness of fit (R^2=0.66) and the height prediction equation was Standing height (cm) = 49.57 + 0.674 Arm span (cm) (20).

A study conducted by Patel, Tanna showed that significant correlation between stature and all five parameters at different degrees. Mathematical formulas were used for estimation of stature from arm span, hand length, hand breadth, foot length, and foot breadth. The formula

were height =34.46+0.78 (Arm span), Height =59.52+5.92 (Hand length), Height =121.69+5.42(Hand breadth), Height =70.37+3.90 (Foot length) and Height =99.05+7.06 (Foot breadth). Arm span showed the highest correlation with stature (r=0.91) followed by hand length, followed by foot length. Hand breadth showed the lowest degree of correlation (0.467) (34).

In the study conducted in Malaysian showed that arm span, demi span and knee height were positively correlated with height. The correlation coefficient was higher among adults (r = 0.81 to 0.90) compared to elderly subjects (r = 0.67 to 0.78), with arm span showing the highest correlation with height in adults and elderly subjects of both genders. Sex specific predictive equations was developed to estimate height from arm span, demi span and knee height derived from adult subjects. The highest r^2 was obtained from the equation developed from arm span. Arm span also showed the lowest SEE value suggesting less measurement error. There was no increment in R^2 value when age was included as an independent variable (35).

Although there are several studies that developed an equation for prediction height from linear body measurements in the different parts of the world, this equations cannot be used for Ethiopians as there is ethnic and racial variability in the relationships. Although, there was a study which tried to develop the height prediction formula based on Ethiopian adults by using arm span(19), the study had limitation. It includes people whose ages are greater than 40 years with declined vertical height which is not appropriate for developing a standard.

3. Significance of the study

Nutritional status of elderly, disabled adults and bed ridden patients were neglected and not assessed because of difficulty and inability of measuring accurate standing height according to standard procedure. And these segments of population were excluded in researches which assess nutritional status based on BMI. In Ethiopia, with an increase in life expectancy and concomitant increase in chronic degenerative diseases, developing an equation that can predict potential height from linear body measurements is a very critical.

This study intends to determine formula to predict height from arm span, half arm span and knee height measurements among Ethiopian adults in Jimma University, Ethiopia. This will help policy makers, program managers and advocators to design policy and manage nutritional problems in elderly, peoples with physical deformity and bed redden patients. Enables health professionals and researchers to assess nutritional status of elderly, people with physical deformity and bed redden patients accurately. It will be also used as a reference for further study.

4. Objectives

4.1. General objective

To develop formula that predict height from arm span, half arm span and knee height measurements and assess its agreement with measured height among Ethiopian adults in Jimma University, Ethiopia, March, 2016.

4.2. Specific Objectives

- ✧ To develop formula that predicts height from arm span
- ✧ To develop formula that predicts height from half arm span
- ✧ To develop formula that predicts height from knee height
- ✧ To examine the agreement between predicted and measured height

5. Methods and Participants

5.1. Study area and period

The study was conducted in Jimma University (JU) from March 15 to April 21, 2016. Jimma University is a public higher educational institution established in December 1999 by the amalgamation of Jimma College of Agriculture (founded in 1952) and Jimma Institute of Health Sciences (established in 1983). Jimma University is located 352 km south west of Addis Ababa at Jimma Town with an area of 409 hectares. It has four campuses, namely Jimma University main campus, Jimma University college of Agriculture and Veterinary Medicine, College of Business and Economics and KitoFurdisa (Jimma University institute of technology). Jimma University named after the city of Jimma. According to 2015/2016, registrar report there are a total of 38,862 (male 27,957, female 10,905) students among these 22,298 (male 16, 160, female 6,138) are regular students in both undergraduate and postgraduate programs. The University accepts students from all parts of Ethiopia which was used as an opportunity for multiethnic representation of the data.

5.2. Study design

A cross sectional study was conducted.

5.3. Population

5.3.1. Source population

All Ethiopian adults who were attending their tertiary education at Jimma University.

5.3.2. Study population

All sampled (selected) Ethiopian adults who were attending their tertiary education at Jimma University in regular program.

5.4.Inclusion and exclusion criteria

Inclusion criteria

- Age range18- 40 years
- Being Ethiopian

Exclusion criteria

- Adults with physical deformity such as kyphosis, scoliosis, bowing of legs and flattening of the plantar arch.
- Adults who has history of physical damage or loss of extremities.

5.5. Sample size determination and sampling procedure

A total of 660 subjects (330 subjects in each sex) were enrolled into this study. This sample size enabled us to detect a correlation coefficient as low as r=0.3 (effect size= 0.15) with 95% confidence level, 80% power and after considering a non-response rate of 5%. Sample size was calculated using GPower version 3.0.10 (36).

A two-stage sampling procedure was employed to select 660 study participants. In the first Colleges were selected. Then in the second stage, we selected study participants by preparing sampling frame in each selected Colleges after stratified by sex and proportional allocation to size (Figure 1).

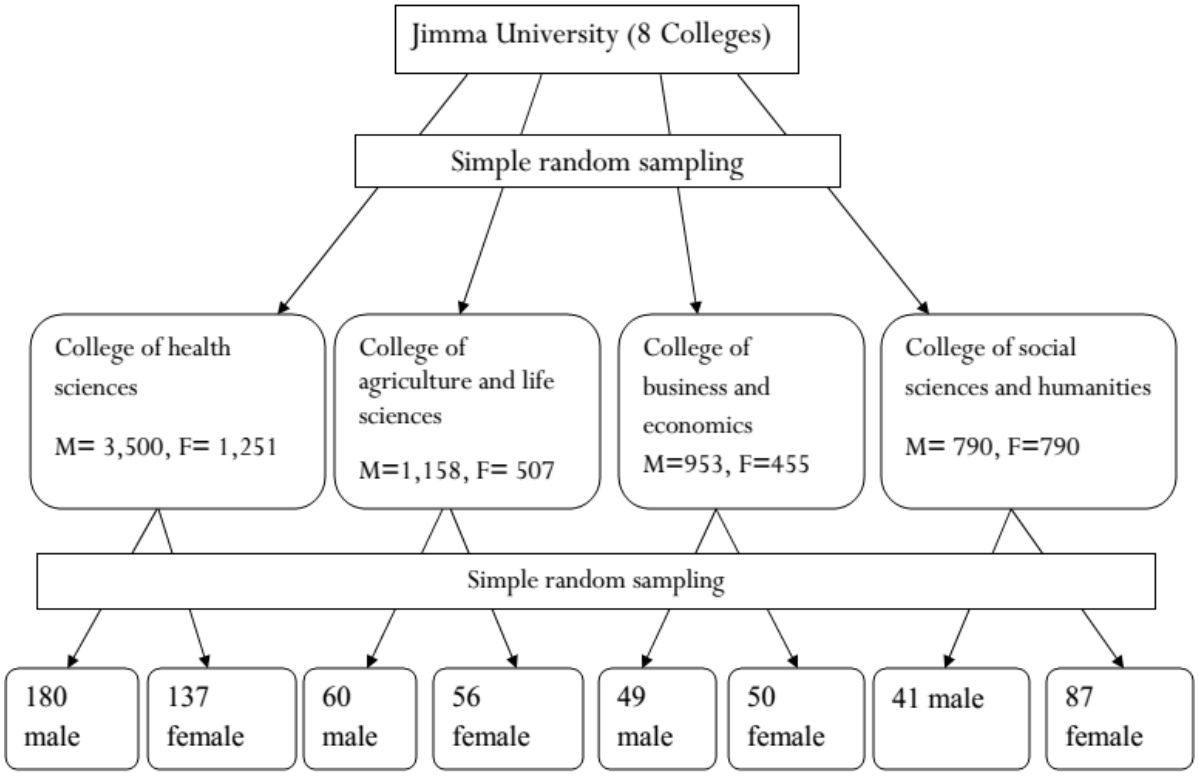

Figure 1Schematic presentation of sampling procedure

5.6. Study variables

Dependent variable

Measured height

Independent variables

- Age
- Sex
- Ethnicity
- Region of residence
- Arm span
- Half arm span
- Knee height

5.7. Data collection

The data were collected through interviewer administered questionnaire and anthropometric measurements. All the participants were interviewed for their age, sex, region and ethnicity information; anthropometric measurements were taken at end of the interview**.** Five human nutrition postgraduate students were trained and recruited for data collection.

Height was measured using a portable Stadiometer (Seca 213, Germany) and recorded to the nearest 0.1cm. During height measurement shoes, pins and braids from the hair that could affect the measurement were removed. Height was measured with the head of participants at the Frankfurt Plane, knees straight and the heels buttocks and the shoulders blades touching the vertical surface of the Stadiometer. Height was measured three times and the average was taken.

The Arm span (in cm) was measured with a stiff tape that avoids flexion errors from the tip of the middle finger on one hand to the tip of the middle finger on the other hand with the individual standing with his/her back to the wall with both arms abducted to 90°, the elbows

and wrists extended and the palms facing directly forward. Arm span was measured three times and the average was taken.

Knee height (in cm) was measured by using locally produced caliper consisting of a vertical scale with two horizontal blades at each end. Subjects were measured in a sitting position with the leg supported so that the knee and ankle was at 90° angle. One of the caliper blades was positioned under the heel of the left foot and the other was placed on the anterior surface of the left thigh just above the condoyle of the femur and just proximal to the patella. The shaft of the caliper was held parallel to the shaft of the tibia, and gentle pressure was applied to the blades of the caliper. The measurement was repeated three times and the average was taken.

Half arm span (in cm) was measured with the subject standing upright with back straight, arms extended sideward at 90° to the torso, fingers stretched and the arm rested against a wall to avoid forward or backward bending. The distance between the tip of the middle finger (not nail tip) and midpoint on the sternal notch was taken using a flat, stiff tape that avoids flexion errors. The measurement was repeated three times and the average was taken.

5.8. Data quality control

Data quality was ensured during data collection, cleaning, entry and analyses. One day intensive training was given for the data collectors. At the end of training, the precision of trainee was assessed by ENA smart software. The principal investigator checked and reviewed all the completed questionnaires to ensure completeness and consistency of collected information. Anthropometric measurements were taken using standardized and calibrated equipment in triplicates for each participant. Pre-test was done on 10% of sample size in Kito Furdisa (Jimma University institute of technology). The supervisors repeated 10% of the anthropometry measurements from each data collector to check reliability of the measurements.

5.9. Data Processing and Analysis

Data were edited, coded and entered into EpiData version 3.1 and exported for cleaning and analyses to SPSS for windows version 20. Descriptive analyses were conducted and the result was presented using tables. Reliability of measurements was checked by

Cronbach'salpha. Normality of regression residual, linear relationship and equality of variance were checked and then linear regression models were fitted to develop height prediction formula from independent variables. Bivariate linear regressions were conducted and p-value ≤ 0.25 was considered as a candidate for multivariable linear regression. Bland-Altman analysis and plots were employed to see the agreement between actual height and predicted height. P-values < 0.05 was used to declare statistical significance.

5.10. Definitions of Terms

- Height is the vertical distance from the heels to the vertex in a subject standing erect.
- Arm span is the distance between the tips of the middle finger of one hand to the tip of the middle finger of the other hand.
- Half arm span is the distance between the tip of the middle finger (not nail tip) and midpoint on the sternal notch.
- Knee height is the distance between the heels of the foot to the upper most part of femur condoyle (about 4 cm. proximal to the patella).
- Adult in this study the age group between 18- 40 years.

5.11. Ethical consideration

The study was conducted after getting written approval from the ethical clearance committee of Jimma University, Collage of Health Sciences. Formal letter was obtained from the president's office and the dean of each college, Jimma University. Informed verbal consent was obtained from all study participants. Each respondent was informed about the objective of the study and confidentiality was kept at each step of data collection and processing. The participants were assured that they have full right to participate or withdraw from the study.

5.12. Dissemination plan

Findings of the study will be presented and submitted to Jimma University, College of Health Sciences, Department of Population and Family Health. The report will also be submitted to FMOH and regional health bureaus of each region. Finally, effort will be made to present the result in various workshops and for publication on a peer reviewed scientific journal.

6. Result

6.1. Characteristics of Study Participants

A total of six hundred thirty eight students participated in the study with an overall response rate of 96.7% (97.0 % for males and 96.4% for females). Majority of the study participants were from Oromiya region (50%) followed by SNNPR (24.3%) and Amhara (8%). Male students constituted 50.2 % of the total study participants (**Table 1**).

Table 1: Distribution of study participants by region and sex, Jimma University, March 2016.

Region	Male (n=320)	Female (n=318)	Total (n=638)
Oromiya	119 (37.2)[1]	200 (62.9)	319 (50)
Amhara	24 (7.5)	27 (8.5)	51 (8.0)
SNNPR	102 (31.9)	53 (16.7)	155 (24.3)
Tigray	10 (3.1)	6 (1.9)	16 (2.5)
AA	8 (2.5)	23 (7.2)	31 (4.9)
Benshangul	11 (3.4)	0 (0.0)	11 (1.7)
Dire dawa	2 (0.6)	2 (0.6)	4 (0.6)
Somalia	19 (5.9)	0 (0.0)	19 (3.0)
Gambella	22 (6.9)	7 (2.2)	29 (4.5)
Harrari	3 (0.9)	0 (0.0)	3 (0.5)

[1]number (percent), all such values

From the 638 study participants, 243 (38.1%) were Oromo, 129 (20.2%) were Amhara and 41(1.6%) were Tigrie by ethnicity. The mean (SD) age of participants was 24.8 (4.1) with 26.7(4.2) for males and 22.8 (2.8) for females (**Table 2**).

Table 2: Ethnicity of study participants by sex among Ethiopian adults in Jimma University, March 2016.

Ethnicity	Male (n=320)	Female (n=318)	Total (n= 638)
Oromo	104 (32.5)[1]	139 (43.7)	243 (38.1)
Amhara	44 (13.8)	85 (26.7)	129 (20.2)
Tigrie	17 (5.3)	24 (7.5)	41 (6.4)
Dawro	10 (3.1)	0 (0)	10 (1.6)
Shinasha	9 (2.5)	0 (0)	9(1.4)
Gamo	13 (4.1)	3 (0.9)	16 (2.5)
Guragie	16 (5.0)	14 (4.4)	30 (4.7)
Hadiya	21 (6.6)	12 (3.8)	33 (5.2)
Welaita	12 (3.8)	23 (7.2)	35 (5.5)
Kembata	12 (3.8)	3 (0.9)	15 (2.4)
Somali	21 (6.6)	0 (0.0)	21 (3.3)
Sidama	11 (3.4)	0 (0.0)	11 (1.7)
Konso	8 (2.5)	0 (0.0)	8 (1.3)
Keffa	4 (1.3)	12. (3.8)	16 (2.5)
Yem	3 (0.9)	3 (0.9)	6 (0.9)
Burji	3 (0.9)	0 (0.0)	3 (0.5)
Agnuack	12 (3.8)	0 (0.0)	12 (1.9)

[1]number (percent), all such values

6.2. Anthropometric Measurements of Study Participants

The mean (SD) of height, arm span, half arm span and knee height of participants were 167.7 (8.2) cm, 174.3 (5.0) for males and 161.1 (4.6) for females; 174.3(9.2) cm, 181.2 (5.7) for males and 167.2 (6.1) for females; 86.8(4.6) cm, 90.2(3.3) for males and 83.4 (2.1) for females; and 51.5 (3.1) cm, 53.8 (2.2) for males and 49.2 (2.1) for females, respectively (**Table 3**). Overall reliability of measurements was checked by Cronbach's alpha and it was 0.92.

Table 3: Mean (SD) anthropometric measurements of study participants in Jimma University, March 2016.

Variables	Male	Female	Total
Height	174.29 (5.0)	161.08 (4.6)	167.71 (8.2)
Arm span	181.22 (5.7)	167.23 (6.1)	174.25 (9.2)
Half arm span	90.22 (3.3)	83.43 (3.1)	86.84 (4.7)
Knee height	53.76 (2.2)	49.23 (2.1)	51.50 (3.1)

There were strong positive correlation between height and arm span, half arm span and Knee height. The correlation coefficient between height and arm span were (r= 0.92 (0.80 for males and 0.77 for females), p<0.001), height and half arm span (r=0.87 (0.62 for male and 0.80 for female), p<0.001) and height and knee height (r=0.88 (0.75 for male and 0.70 for female), p<0.001) (**Table 4**).

Table 4: The correlation of arm span, half arm span and knee height measurements with height among Ethiopian adults in Jimma University, March 2016.

Variables	Male	Female	Total
Height and arm span	0.80**	0.77**	0.92**
Height and half arm span	0.62**	0.80**	0.87**
Height and knee height	0.75**	0.70**	0.88**

** *p< 0.001;*

6.3. Prediction of Height from Arm Span, Half Arm Span and Knee Height

In multivariable linear regression analyses arm span and sex, half arm span and sex and knee height and sex significantly predicted height measurement (p-value < 0.05) (**Table 5**).

In the height prediction equation using arm span, a unit increase in arm span was associated with a 0.63 unit (p<0.001) increase in height measurement while adjusted for sex. Similarly, sex was found to be important predictor in this model with male subjects on average 4.33 units higher than their female counterparts (p<0.001) arms span measurements taken

constant. So, the height prediction equation become **Height = 59.30 + 0.63 (arm span) – 4.33 (sex); where sex=1 for females & 0 for males.**

In the height prediction equation using half arm span, a unit increase in half arm span was associated with a 1.05 unit ($p<0.001$) increase in height measurement while adjusted for sex. Similarly, sex was found to be important predictor in this model with male subjects on average 6.12 units higher than their female counterparts ($p<0.001$) half arms span measurements taken constant. So, the height prediction equation become **Height = 79.93 + 1.05 (half arm span) – 6.12(sex); where sex=1 for females & 0 for males.**

In the height prediction equation using knee height, a unit increase in knee height was associated with a 1.63 unit ($p<0.001$) increase in height measurement while adjusted for sex. Similarly, sex was found to be important predictor in this model with male subjects on average 5.84 units higher than their female counterparts ($p<0.001$) knee height measurements taken constant. So, the height prediction equation become **Height =86.79 +1.63 (knee height) -5.84 (sex); where sex=1 for females & 0 for males**

Table 5: Prediction of height from arm span, half arm span and knee height in Ethiopian adults in Jimma University, March 2016.

Variables	B (95% CI)[1]	SE	*p*-value
Model predicting height from arm span[2]			
Arm span	0.63 (0.60, 0.68)	0.02	<0.001
Sex	-4.33 (-5.04, -3.61)	0.36	<0.001
Constant	59.30 (52.22, 66.39)	3.61	<0.001
Equation model to predict height from half arm span [3]			
Half arm span	1.05(0.96, 1.13)	0.04	<0.001
Sex	-6.12(-6.88, -5.33)	0.40	<0.001
Constant	79.93(72.41, 87.44)	3.83	<0.001
Equation model to predict height from Knee height [4]			
Knee height	1.63(1.51, 1.75)	0.06	<0.001
Sex	-5.84(-6.58, 5.10)	0.38	<0.001
Constant	86.79(80.41, 93.17)	3.25	<0.001

[1] B: beta coefficients from linear regression models

[2]: R^2=0.87; Adjusted R^2=87; Standard error of the estimate (SEE) =2.96 cm

[3]: R^2=0.83; Adjusted R^2=83; Standard error of the estimate (SEE) =3.41 cm

[4]: R^2=0.84; Adjusted R^2=0.84; Standard error of the estimate (SEE) =3.26 cm

6.4. The Agreement between Measured Height and Predicted Heights

The result of Bland-Altman analyses showed that mean of the difference between measured height and predicted heights were not statistically significant from zero. The mean (SD) of the difference between the measured height and predicted height was 0.09(2.96) cm,(p =0.46) based on arm span;-0.01(3.41) cm, (p= 0.97) based on half arm span; and -0.01 (3.26) cm,(p= 0.92) based on knee height (**Table 6**).

Table 6: Bland-Altman analyses of measured and predicted height of Ethiopian adults in Jimma University, March 2016.

Variables	Mean(SD)	Mean difference (SD)	95% limit of agreement	p-value
Measured height	167.71(8.15)			
Measured Arm span	174.25(9.15)	-6.54(3.68)	--------	0.000
Predicted height from arm span	167.62(7.59)	0.09(2.96)	-5.71, 5.88	0.460
Predicted height from half arm span	167.71(7.46)	-0.01(3.41)	-6.69, 6.67	0.966
Predicted height from knee height	167.72(7.47)	-0.01(3.26)	-6.40, 6.40	0.915

[1]Comparison was assessed by paired T-test by taking mean of measured height equal to mean of measured arm span and predicted heights.

The result of Bland-Altman plot showed that the mean difference (95% limit of agreement) between the measured height and predicted height was0.09 (-5.71, 5.88 cm) based on arm span;-0.01(-6.69, 6.67 cm) based on half arm span; and -0.01 (-6.40, 6.40 cm) based on knee height. In all plots there were no pattern and majority of observations were within the 95% limit of agreement (Figure 2 to 4).

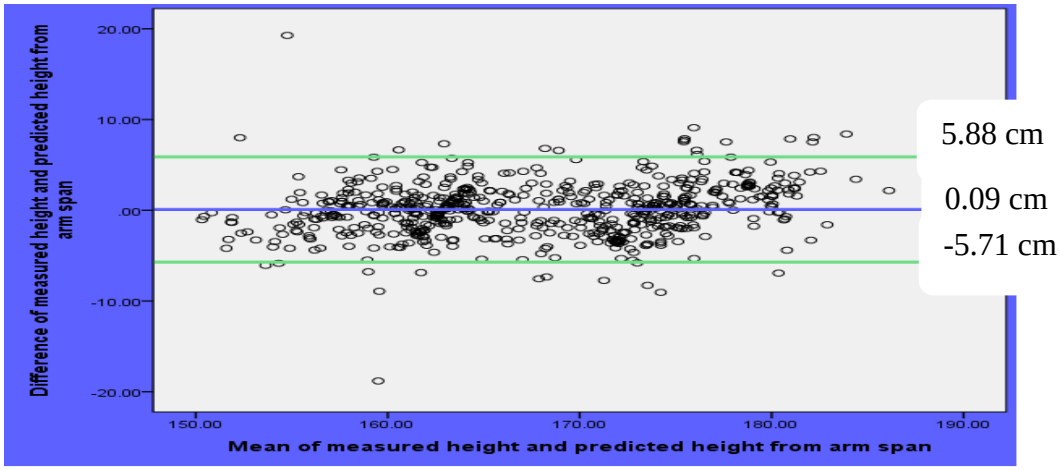

Figure 2: Bland-Altman plot of measured height and predicted height from arm span among Ethiopian adults in Jimma University, March 2016.

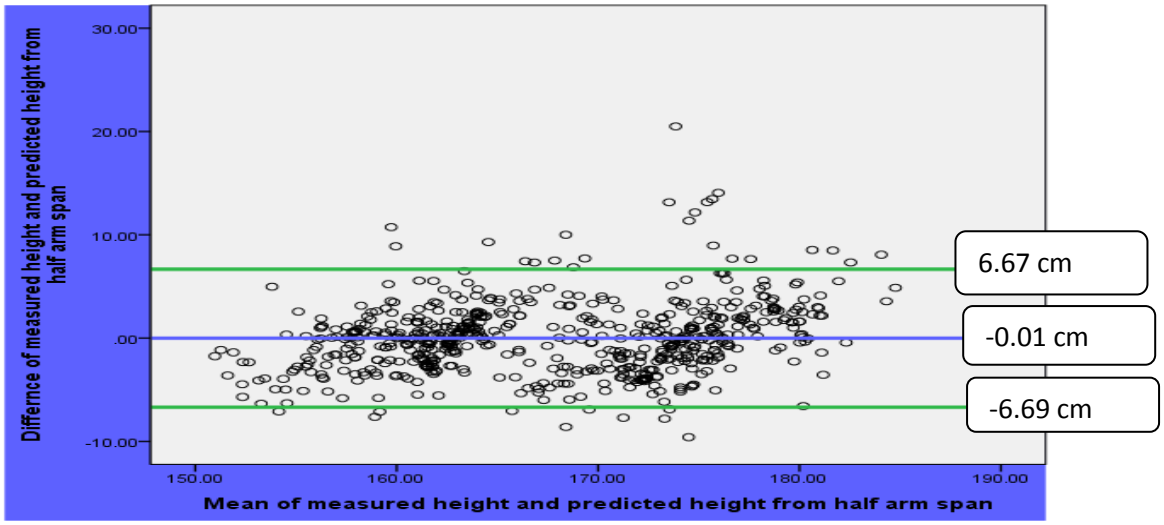

Figure 3Bland-Altman plot of measured height and predicted height from half arm span among Ethiopian adults in Jimma University, March 2016.

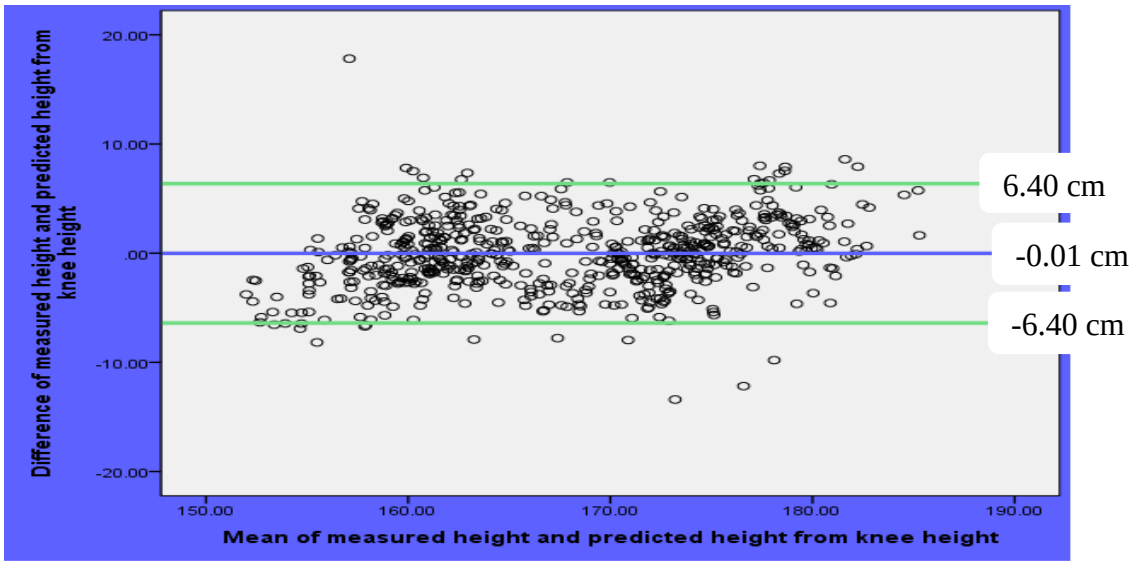

Figure 4: Bland-Altman plot of measured height and predicted height from knee height among Ethiopian adults in Jimma University, March 2016.

7. Discussion

This study demonstrated that measurements of linear body parts such as arm span, half arm span and knee height can be valid predictors of height which has an important application in nutritional assessment of Ethiopian at advanced age and in the presence of skeletal deformity or severe illnesses. Several studies evaluated the prediction of height using different physical measurements (20, 31-34). The physical measurements that were proven to be consistently reliable were arm span and knee height (20, 31-32). In this study we used arm span, half arm span and knee height to predict height which showed good agreement between measured height and predicted height.

The finding of this study showed that the mean height was less than the mean arm span in participants of both sex which is in agreement with the reports of studies conducted in North India and Garo Tribal Bangladesh (21, 22), and in disagreement with the findings of studies conducted among Serbian and Bosnian and Herzegovinian adults, where arm span exceeded height in male participants, while arm span was less than height in female participants (23, 24). Moreover, the study done in Nepal and Chakma showed the mean arm span and height were equal (26, 27). This finding indicates the need for developing prediction equation instead of using arm span as direct estimate of height which is in contrast to what has been shown by the study conducted in Nigeria (37).

The results of this research further indicate that, a strong positive correlation was observed between height and arm span, half arm span and knee height with the correlation coefficient of 0.92 (0.80 for males and 0.77 for females), 0.77 (0.62 for males and 0.56 for females) and 0.88 (0.75 for males and 0.70 for females), respectively. The correlation coefficients were similar with that of the study conducted in Bangladeshi female subjects, Bosnian and Herzegovinian adults, Alva's education foundation, Chakma females, Medical Students of Maharashtra, Gujarat and Patel with correlation between height and arm span ranging from 0.8 to 0.9 (22, 24, 25,27, 30, 31and 34); whereas different with a study conducted in Nepal which showed moderate positive correlation between height and arm span with correlation coefficient of 0.68 for males and 0.51 for females (26).A study conducted in Thai adult women also showed strong positive correlation between height and knee height with a correlation coefficient of 0.84 (32). Likewise, a study conducted in northern India showed a

strong correlation in the total population (0.78) and male study subjects (r=0.75) with a moderate correlation in female study subjects (r= 0.51)(29).

Multivariable linear regression model revealed that arm span and sex, half arm span and sex and knee height and sex predict height significantly ($p< 0.01$),which is similar with the study conducted in North India, Serbia, Bosnian and Herzegovinian, Nepal, medical students of Maharashtra and Gujarat (21, 23, 24, 26, 30-31). Based on the R^2, arm span was found to be the best predictor of height compared to all the three height prediction models.

In all our prediction equations, age of subjects was not found to be important covariate for all models. As a result it was ignored in the final prediction equation. This finding is not in agreement with other studies (32, 33). The probable reason for such a difference could be that in our study we selected adults in the age group 18-40 years, the age group during which height does not start shrinking (14). This suggests the superiority of our prediction equations that were developed based on data where age has limited effect on maximum attainable height.

The developed height prediction equations from arm span were satisfactory in terms of regression model with the high R^2 (0.87) which is higher than the study conducted in Nepal (R^2=0.75 for males and R^2=0.68 for females), Medical Students of Maharashtra (R^2=0.79 for males and R^2=0.81 for females), Bosnian and Herzegovinian Adults (R^2=0.767 for males and R^2=0.787 for females), North India (R^2=0.82 for both sexes) and Serbian adults (R^2=0.66 for males andR^2= 0.68 for females) (21, 23 24, 26, 30) and an acceptable standard error of estimation (2.96 cm). Moreover, the Bland- Altman analyses and plot showed good agreement between measured height and predicted height from arm span.

Similarly, the developed height prediction equations from half arm span were acceptable in terms of regression model with the high R^2 (0.77) and an acceptable standard error of estimation (3.95 cm). Moreover, the Bland- Altman analyses and plot showed that there was good agreement between measured height and predicted height from half arm span.

Similar to the above findings, the developed height prediction equations from knee height were satisfactory in terms of regression model with the high adjusted R^2 (0.84) which is greater than the study done in Thai adult women adjusted R^2 (0.72) and North India R^2 and

adjusted R^2 (0.6 and 0.06) (28, 29) and an acceptable standard error of estimation (3.26 cm) which was greater than the study done in Thai adult women with standard error of estimation (2.8 cm) (28). Moreover, the Bland- Altman analyses and plot showed a good agreement between measured height and predicted height from knee height.

Our findings have practical implications in the wake of an increasing life expectancy and tendency towards an increase in elderly population in Ethiopia on the one hand and the concomitant increase in the risk of chronic non-communicable diseases on the other. The height prediction equations generated from the regression models can be used by researchers, policy makers and program planners working on elderly people, people with skeletal deformity and bed ridden patients to develop and evaluate nutritional intervention programs.

Strength of the study

The strengths of this study were First of its kind, high response rate, used standardized quality control measures and high reliability of measurements

8. Conclusion and Recommendations

8.1. Conclusion

Height can be predicted from arm span, half arm span and knee height when measuring standing height according to the standard procedure is not possible. Arm span is the best predictor of height. The findings imply that these equations can be used to assess the nutritional status of bed ridden patients, peoples with disability and elderly population in Ethiopia by predicting height.

This is an important input for researchers and program implementers in the light of increasing life expectancy and chronic degenerative diseases at an advanced age. So, clinicians and researchers can use the developed equations to predict height when measuring standing heights were not possible for Ethiopian population.

8.2. Recommendations

- ✓ Federal ministry of health and region health bureau have to develop guideline to assess the nutritional status of elderly, peoples with skeletal deformity and bed ridden patients based on the developed equation
- ✓ Clinicians and researchers have to use the developed equations to predict height from arm span, half arm span and knee height which is used to assess the nutritional status of elderly, peoples with skeletal deformity and bed ridden patients.

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Annex one: Questionnaire

JIMMA UNIVERSITY COLLEGE OF HEALTH SCIENCES SCHOOL OF GRADUATE STUDIES DEPARTMENT OF POPULATION AND FAMILY HEALTH; HUMAN NUTRITION UNIT.

CONSENT AND INFORMATION SHEET.

My name is_____, I am here on behalf of Jimma University, College of Health Sciences, and Department of population and family health. I am doing this study for the partial fulfillment of the requirements for a master's of science in human nutrition.

The objective of this study is to develop formula that predicts height from arm span, demi span and knee height measurements among Ethiopian adults in Jimma University, Ethiopia, February 2016

Your cooperation and honestly participation in filling questionnaires will provide us valid result and show us our real status and help to make intervention; hence we request to participate honestly. Your participation in filling the prepared questionnaires and every aspect of the study is completely voluntary. Your name will not be written in this form and all information that you give us will be kept confidential. You may skip any question that you prefer not to answer, but we would appreciate your cooperation. You may also ask us to clarify questions if you don't understand them or can stop the interview at any time. Your responses to our questions are identified only by number, never by name. Do you agree to participate in this study?

Yes … …….2. No…….

Thank you for your participation!

Name of the data collector……Signature ……Date ……..……

Name of supervisor ……..Signature……..….Date…….....

Questionnaire

1. Id no ----------
2. Age _____Completed Years
3. Sex 0) Male

    1) Female

4. Region you come from ……..
5. Ethnicity

    1) Oromo
    2) Amhara
    3) Tigrie
    4) Dawro
    5) Gurage
    6) Kefa
    7) Somali
    8) Gambella
    9) Other (specify) _____

6. Height 1_____Height2_____Height3_____
7. Arm span 1_____ Arm span 2_____ Arm span 3_____
8. Half arm span 1_____ Half arm span 2_____Half arm span 3_____
9. Knee height 1_____ Knee height 2_____ Knee height 3_____