

# Height Estimation using Arm Span as a Proxy among Ghanaians

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## ABSTRACT

Height is an important anthropometric tool and most popular characteristic parameter employed in human identification. However, body height cannot always be ascertained by direct measurement due to various deformities of the extremities in patients with injuries. There is accumulating evidence to demonstrate the use of arm span measurements in the estimation of height but there is very little information on the use of arm span measurements in Ghana. Therefore, this study sought to determine the relationship between height, arm span and sex as well as the correlational efficiency of using arm span as a surrogate for height. This cross-sectional study recruited 716 participants [328 males and 388 females] aged 18 to 30 years. Ethical approval and informed participant consent were sought. Male participants were taller and had wider arm span than the females with a statistically significant value [ $p < 0.001$ ]. The results also showed that, the mean arm span measurement was higher than the mean height measurement with values of males [arm span: 180.57 cm; height: 170.79 cm] and females [arm span: 168.60 cm; height: 161.19 cm]. There was a statistically significant strong positive correlation [ $p < 0.001$ ] between the arm span and height in the male, female and pooled sample with “r” values of 0.815, 0.788 and 0.873 respectively. Sex-specific equations to predict height from arm span measurements among Ghanaians were established. This study has developed sex specific equations to predict height from arm span measurements and has proved that arm span can effectively predict height using regression equations.

**KEY WORDS:** Height, Arm Span, Ghana, Identification, Forensic, Anthropometry.

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## INTRODUCTION

Height is an important parameter for the assessment of the growth of an individual and is documented to vary from one population to the other [1,2]. The dimensional relationship between body parts and the whole body

has been the focus of anatomists, anthropologists and forensic scientists for many years [3]. Height can be accurately determined when the skeletal maturity of an individual is fully attained and without any skeletal deformity. However, in some cases, measurement of

height is difficult or impossible because of deformities of the trunk or legs, fractures, lower limb amputation or contractures in patients who are unable to stand [3]. In such circumstances, an estimate of body height has to be derived from other reliable anthropometric indicators such as forearm length [4], hand and foot lengths [5–7], arm span [2,8–14], knee height [15–17], sternal height [18–20], length of vertebral column [18,21,22], sitting height [23–25], scapula length [26–28], cranium [29,30] and facial measurements [5,31,32].

Estimation of stature plays an important role in the identification of individuals [33]. Furthermore, it is useful in situations where only mutilated and fragmentary remains are available for examination due to mass disasters both natural and man-made such as earth quakes, tsunamis, hurricanes, flood, terror attacks, bomb blast, mass accidents, explosions, railway accidents, wars and plane crashes [3]. Arm span has been used as a surrogate for height, but not feasible in people with shoulder or arm contractures [11]. The associations of arm span and body height however do vary in different ethnic and racial groups [34]. In anthropometry, arm span is the most reliable parameter for the prediction of the height of individuals [12]. Several studies used arm span measurements in the estimation of height but there is very little information on the use of arm span measurements in Ghana. Therefore, the objective of this study was to determine the relationship between height, arm span and sex as well as the correlational efficiency of using arm span as a substitute for height among Ghanaians.

## METHODS

This cross-sectional study recruited 716 Ghanaian participants, 328 males and 388 females using the simple random sampling method at the Department of Anatomy, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. The average age of the participants was  $19.24 \pm 1.64$  years with a range of 18 - 30 years. Informed Participant consent was sought. Ethical approval was given by the Committee on Human Research, Publication and Ethics of

the School of Medical Sciences, Kwame Nkrumah University of Science and Technology and the Komfo Anokye Teaching Hospital with reference number: CHRPE/AP/129/20. Participants with any skeletal deformity of the upper and lower limbs, amputees and non-Ghanaians were excluded from the study. The data collection was done from September 2018 to March 2020.

**Data Collection:** The sex and age of the participants were determined as recorded on the consent form. The anthropometric parameters, including body height and arm span were taken according to the protocol of the Handbook of physical measurements [35].

**Data quality control:** Data was collected by two anatomists with knowledge in anatomical positioning and anatomical landmarks in order to achieve the required data quality. Non-significant values for both inter and intra-observer errors were obtained following a preliminary study to ascertain the reliability of the data.

**Data Analysis:** The analysis was carried out using Statistical Package for Social Sciences [SPSS] version 23.0. The data was normally distributed. Means and standard deviations [SD] were obtained for both anthropometric variables. A comparison of means of body height and arm span with respect to sex was carried out using t-test. The relationship between body height and arm span was established using Pearson's correlation coefficients. Linear regression analyses were performed to examine the extent to which arm span can reliably predict body height. Statistical significance was set at  $p < 0.05$  [95 % confidence level].

## RESULTS

The mean arm span for the male participants was  $180.57 \pm 8.22$  cm with a range of 160.20 – 200.40 cm whereas the mean height was  $170.79 \pm 7.87$  cm with a range of 151.55 – 188.80 cm. The mean arm span for the female participants was  $168.60 \pm 7.81$  cm [144.75 – 191.60 cm] whereas the mean height was  $161.19 \pm 6.05$  cm [140.00 – 180.10 cm]. The mean arm span for the pooled population was  $174.08 \pm 9.98$  cm with a range of

144.75 – 200.40 cm whereas the mean height was  $165.59 \pm 7.87$  cm with a range of 140.00 – 188.80 cm.

The mean arm span for the male participants was  $9.78 \pm 4.77$  cm more than the body height and was statistically significant [ $t = 37.130$ ;  $p < 0.001$ ], for the female participants, the mean arm span was  $7.40 \pm 4.81$  cm more than the body height and was also statistically significant [ $t = 30.302$ ;  $p < 0.001$ ]. The pooled mean arm span was  $8.49 \pm 4.93$  cm and was also statistically significant [ $t = 46.053$ ;  $p < 0.001$ ]. Also, the mean height of the male participants was  $10.89 \pm 7.80$  cm more than that of the female participants and was statistically significant [ $t = 25.266$ ,  $p < 0.001$ ], whereas the mean arm span of the male participants was  $13.58 \pm 9.48$  cm more than that of the female participants and was statistically significant [ $t = 25.950$ ,  $p < 0.001$ ].

**Table 1:** Correlation between Body Height and Arm Span of the Study Subjects.

	r	95% Confidence Interval	p- value
Male	0.815	0.594 – 0.693	< 0.001
Female	0.788	0.563 – 0.658	< 0.001
Pooled	0.873	0.661 – 0.717	< 0.001

**p** = probability, statistically significant difference [ $p < 0.05$ ], **r** = Correlation Coefficient

The correlation coefficient between height and arm span was 0.815, 0.788 and 0.873 for males, females and the pooled sample respectively. All the correlation coefficients for the males, females and the pooled sample indicates a significantly strong, positive linear relationship between arm span and height statistically [ $p < 0.001$ ] [Table 1].

**Table 2:** Linear Regression Analysis for the Prediction of Height Using Arm Span.

	R <sup>2</sup>	Adj. R <sup>2</sup>	SEE	Regression Equations	p- value
Male	0.664	0.663	3.77	$54.605 + [0.643*MA]$	< 0.001
Female	0.621	0.62	3.733	$58.291 + [0.610*FA]$	< 0.001
Pooled	0.762	0.762	3.839	$45.632 + [0.689*PA]$	< 0.001

**R<sup>2</sup>** = coefficient of determination, **Adj. R<sup>2</sup>** = adjusted coefficient of determination,

**SEE** = Standard Error of Estimate, **MA** = male arm span, **FA** = Female arm span,

**PA** = pooled arm span, **p** = probability, statistically significant level [ $p < 0.05$ ]

Table 2 shows the results of linear regression of the anthropometric parameters. The results show that, arm span can significantly predict height of the Ghanaian population [ $p < 0.001$ ], with an adjusted coefficient of determination of 66.3%, 62% and 76.2% for the males, females and the pooled respectively. The Table also shows regression equations for stature estimation using the arm span measurements obtained in the study. In males, Height =  $60.695 + [0.609*MA]$ . In females, Height =  $63.525 + [0.580*FA]$  and in the pooled, Height =  $49.536 + [0.667*PA]$ . The regression equation for the pooled data gave the best prediction value.

**Table 3:** Paired Sample t-test between actual and predicted height of participants.

Sex	AMH $\pm$ SD [cm]	PMH $\pm$ SD [cm]	MD	SED	95% CI Lower	Upper	T	p-value
Male	$170.79 \pm 6.49$	$170.71 \pm 5.28$	0.08	0.208	-0.329	0.488	0.383	0.702
Female	$161.23 \pm 6.13$	$161.18 \pm 5.11$	0.06	0.189	-0.314	0.43	0.306	0.76
Pooled	$165.59 \pm 7.87$	$165.57 \pm 6.87$	0.02	0.143	-0.266	0.297	0.109	0.914

**cm** = centimeter, **SD** = Standard Deviation, **T** = t-statistic; **p** = probability, statistically significance level, **AMH** = Actual Mean Height, **PMH** = Predicted Mean Height, **MD** = Mean Difference, **SED** = Standard Error of Difference, **CI** = Confidence Interval

Paired Samples t-test was conducted to evaluate the existence of mean difference between the actual and predicted height of the participants. The highest mean difference was recorded for the males followed by the females and then the pooled sample. However, these differences were not statistically significant as shown in Table 3 above.

## DISCUSSION

Anthropometry is the external description and measurement of the human body parts for comparison purposes and establishing norms for sexual dimorphism, age and race [36]. The prediction of height using arm span measurement has been attempted by many authors [13,34,37–39]. This study has provided an update on average body heights among Ghanaian males and females.

**Height Measurement:** Height is a significant parameter for the assessment of growth and development of an individual. Height varies from one population to another and also with

age [1]. In the present study, male participants were taller than the females with statistically significant sex difference [ $p < 0.001$ ]. A similar study conducted by Kasunka *et al.* [2015] in Dakshina Kannada district India revealed that, adult males were taller than adult females with a mean height of  $167.93 \pm 6.98$  cm and  $157.38 \pm 6.96$  cm respectively [ $p < 0.001$ ]. Venkataraman *et al.* [2015] reported the pooled mean height of an Indian population to be  $162.75 \pm 9.26$  cm [40]. A person's height could be influenced by indicators such as rate of growth, body size, physiological variables, physical capacities and nutritional status of the human body [41,42]. Despite all these factors, the similarities in the present study and the other studies may be due to the fact that, the duration of pubertal growth is longer in boys than in girls resulting in the ossification of bones ceasing earlier in females than in males contributing to an appreciable increase in height of males than females [43–45].

**Arms Span Measurements:** In the determination of arm span from the present study, the male group had a wider arm span compared to that of the females. A statistically significant difference between male and female arm span was established [ $p < 0.001$ ]. Results from the present study was in agreement with that by Kasunka *et al.* [2015], which included 153 participants [20 – 25 years] and recorded the mean arm span for females as 161.63 cm and 176.2 cm for males. In a similar study by Venkataraman *et al.* [2015] the mean arm span was  $169.83 \pm 8.17$  cm. Observations made from both the present and similar studies show that, males have a greater arm span than females. Biologically males have larger, more robust skeletal elements and greater muscle mass than females.

**Comparison of Height and Arm Span Measurements:** The results of this study showed that, the mean arm span measurement was higher than the mean height measurement among Ghanaians with values of males [arm span: 180.57 cm; height: 170.79 cm] and females [arm span: 168.60 cm; height: 161.19 cm] which are similar but lower in comparison to the mean arm span and height in a research conducted among the Urhobos in the Delta

State of Nigeria which showed that, male arm span and height were  $184.56 \pm 9.54$  cm and  $173.0 \pm 7.7$  cm while females had arm span and height measurements of  $173.61 \pm 9.07$  cm and  $164.6 \pm 7.0$  cm respectively [38]. Another study with higher values than the present study was conducted among Nigerian adults of the Bekwara ethnic group of Cross River State by Esomonu *et al.* [2015] where mean arm span was found to be 184.57 cm in males and 172.77 cm in females and height of males and females to be 169.73 cm and 163.00 cm respectively [34]. However, the height of the Ghanaian male was only numerically higher than the Bekwara ethnic group study and not statistically significant. On the other hand, the values of the present study were higher than the values in another study by Ter Goon *et al.* [2011] in Benue State University who found male arm span of  $173.20 \pm 9.10$  cm and height of  $167.40 \pm 6.60$  cm with female arm span of  $164.20 \pm 9.90$  cm and height of  $160.20 \pm 9.20$  cm in Nigerian adults. A study in India by Singh *et al.* [2012] found the average arm span in Northern Indian males and females to be 166.4 cm and 157.44 cm respectively and height to be 165.96 cm in males and 156.4 cm in females which are also lower as compared to the values of this study [46]. Arifi *et al.* [2017] in a study conducted on adolescents aged between 18-20 years in Kosovo found that, male arm span was  $180.91 \pm 6.92$  cm with height of  $178.60 \pm 5.73$  cm while females recorded  $165.60 \pm 6.03$  cm and  $165.33 \pm 4.45$  cm for arm span and height respectively. Popovic *et al.* [2016] in a study among Macedonian adults, recorded male and female arm span values of  $178.78 \pm 7.71$  cm and  $164.41 \pm 6.42$  cm and heights of  $178.10 \pm 6.79$  cm and  $164.58 \pm 5.40$  cm for males and females respectively [47]. On the other hand, a study conducted in a Kosovan population showed that, the average Kosovan male arm span and height were recorded as  $181.20 \pm 7.02$  cm and  $179.52 \pm 5.96$  cm respectively and the average female arm span and height were  $165.60 \pm 5.87$  cm and  $165.72 \pm 4.93$  cm respectively [37].

This places Kosovans among the tallest nations in Europe and to a larger extent, the world. The difference in height between the present



study and that reported by other researchers can be explained by the different environmental factors, different genetic constitution and nutrition across populations which play important roles in human growth and development [48].

The use of various anthropometric indicators for the prediction of stature is very evident from the past decades and it has been analyzed by many researchers. Nonetheless, it is important to note that, arm span has been found to be the most reliable body measurement for prognosticating the height of an individual [2,13,37]. The relationship between stature and arm span has been assessed among Europeans [3] and in Africans [49]. It has been reported that, equations for estimating height varies from race to race as well as ethnic group to ethnic group [37].

**Estimation of Height from Arm Span Measurement:** There was a statistically significant strong relationship [ $p < 0.001$ ] between the arm span and height in the male, female and pooled populations with correlation coefficient values of 0.815, 0.788 and 0.873 respectively. This is in strong agreement with studies of other research works in different populations where strong associations were found between arm span and height with values of  $r = 0.891$  for women;  $r = 0.840$  for men [50],  $r = 0.989$  [pooled] [51],  $r = 0.806$  for women;  $r = 0.756$  for men [52] and  $r = 0.933$  [pooled] [53]. The correlation coefficient of this study on the other hand is higher than that observed in some other studies; [38] with “ $r$ ” values of 0.509: male; 0.498: female in Nigeria, [13] with “ $r$ ” value in percentages for males being 67.626 and 55.156 for females with a combined “ $r$ ” value of 0.83 also in Nigeria. In a study conducted by Arifi *et al.* [2017] in a Kosovan population, it was recorded that, correlation coefficient between arm span and height for males and females was 0.794 and 0.766 respectively.

The linear regression equation derived for the prediction of male height in this study group was  $54.605 + [0.643 \times \text{Arm span}]$ , while that of females was  $58.291 + [0.610 \times \text{Arm span}]$  and that of the pooled population being  $45.632 + [0.689 \times \text{Arm span}]$  with an adjusted  $R^2$  of

66.3%, 62%, and 76.2% respectively. The models from this study indicates that 66.3%, 62% and 76.2% of the total variation in height is significantly accounted for by the change in arm span within the range of values of arm span for the Ghanaian males, females and the pooled sample respectively. These equations derived in this study were totally different from that of other studies. The regression equations for the males and females of the Benue State indigenes of Nigeria which were [ $\text{stature} = 67.63 + 0.577 [\text{arm span}]; r = 0.77$ ] and [ $\text{stature} = 55.16 + 0.642 [\text{arm span}]; r = 0.72$ ] respectively has a slightly higher coefficient of determination than that in the present study. These differences could be attributed to the different population or sample characteristics. In Malawian children, height of boys and girls were predicted as  $17.043 + [0.348 \times \text{age}] + [0.815 \times \text{arm span}]$  and  $18.158 + [0.265 \times \text{age}] + [0.817 \times \text{arm span}]$  respectively [54]. Yet, in another research conducted among the Bekwara ethnic group in Cross River State of Nigeria, the equation derived for the males and females were  $25.71 + [0.781 \times \text{arm span}]$  with a recorded mean predicted height value of 158.2 cm for males and  $31.83 + [0.753 \times \text{arm span}]$  with height prediction value of 154.0 cm for females [34]. Among Medical Students of Maharashtra in India, the equation for the estimation of height from arm span in males was  $31.25 + [0.80 \times \text{arm span}]$  and in females, it was  $33.54 + [0.77 \times \text{arm span}]$  [3]. The Paired Samples t-test conducted in this study to evaluate the existence of mean differences between the actual and predicted height of participants showed no statistically significant differences with values of  $p = 0.702$ ,  $p = 0.760$  and  $p = 0.914$  for male, female and pooled populations respectively. These values clearly show that, the regression equations derived in this study can be used to effectively predict the height of Ghanaian individuals in situations such as bed ridden patients or in accident cases where the standing height is impossible or difficult to measure.

## CONCLUSION

In this study, males were significantly taller than females. Arm span measurements were greater in males than in females and were

statistically significant. The study showed a strong positive correlation between height and arm span in both males and females. This study has also developed sex specific equations to predict height from arm span measurements among Ghanaians with the pooled equation being the best predictor followed by the male-specific equation and then the female-specific equation. These equations are only applicable within the stated range of the arm span measurements of the Ghanaian population since these equations are population-specific. The study has also provided data for forensic anthropologists and health workers to help in drug administration when patient actual height cannot be easily measured and it is a significant identification parameter which can be used in medico-legal cases.

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