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*Original Research Article*

# Anthropometric Study of Correlation between Arm Span and Stature in Indian Rajasthani Young Adults

**Priyanka Katara[1], Rajesh Arora[1], Rajeev Sharma[2]**

[1]Department of Anatomy, SMS Medical College, Jaipur, Rajasthan, INDIA.
[2]RDBP Jaipuriya Hospital, Jaipur, Rajasthan, INDIA.

## ABSTRACT

**Introduction:** Stature is an important anthropometric tool in different clinical and non-clinical settings. Arm span has been suggested as an alternative method for predicting stature in situations where direct measurement of stature is not possible.
**Aim and Objective:** To find out correlation between arm span and stature in Indian Rajasthani males and females aged between 21 to 30 years and to derive a regression equation between two anthropometric parameters.
**Materials and Methods:** A cross sectional study was designed with 100 Rajasthani males and 100 Rajasthani females between 21 to 30 years of age. Direct measurements of arm span and stature were taken by using stadiometer and a flexible steel tape and were termed as actual arm span ($as^{act}$) and actual stature ($stat^{act}$). Data obtained was then statistically analysed to find out correlation and regression equation between arm span and stature in males and females seperately.
**Results:** Mean value of $stat^{act}$ was 170.84±6.46 cm in males and 157.54±5.80 cm in females. Mean value of $as^{act}$ was 178.47±8.47 cm in males and 161.86±6.87 cm in females. Stature and arm span were strongly correlated via a firm linear rule in both males ($r=0.968$, $p<0.0001$) and females ($r=0.966$, $p<0.0001$). After finding slope and intercept following regression equations were derived-
**For male-** Stature (in cm)=38.89+0.74 arm span (in cm)
**For female-** Stature (in cm)=25.64+0.81 arm span (in cm)
**Conclusion:** Armspan is an acceptable surrogate measure to find stature of a person particularly in the situation where direct measurement of stature is difficult to measure.

**Keywords:** Armspan, Anthropometry, Correlation, Stature.

***Correspondence to:**
**Dr. Priyanka Katara,** D-9/187, Chitrakoot Scheme, Jaipur, Rajasthan, India.
Email: dr.pkatara@gmail.com

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## INTRODUCTION

Pulmonary function test, vital capacity, surface area, and Glomerular Filteration Rate are directly affected by stature[1,2]. Stature is also a direct indicator of basic energy requirement, body mass index, nutritional status and growth of any individual[3]. Estimation of stature is helpful in identifying persons with skeletal dysplasia, musculoskeletal deformity and disproportionate growth abnormalities. It is also helpful in predicting loss of stature that may be age-related or due to the surgical procedures on spine. Estimation of stature is very convienient and simple by directly measuring Head to toe length. But, this simple task becomes very difficult among certain group of people, for example- mental retardation, post spinal surgery, after hip fracture, amputation, bedridden or comatose patient and also those on wheel chair or having osteoporosis[1,4]. Similarly, in older people the measurement of standing height cannot be taken directly because of mobility problem and kyphosis. Estimation of stature has been done by many indirect methods in such cases. These methods include estimation of stature by arm span, demi span, knee height, head length, foot length, hand length, hand phalangeal length, vertebral column length, lower leg length, stride length[1,3-5]. Estimation of stature by arm span measurements was tried in different parts of world by different workers/researchers. It was found that arm span method is the most reliable and most feasible method because arm span doesn't varies significantly with age[5]. Further, assessment of stature by arm span measurement could be done by three methods:- 1) by direct substitution by arm span; 2) by application of fixed correction factor based on ratio of arm span and standing height; and 3) by linear regression analysis[2,6]. Regression analysis method is found to be most accurate with least error among all[2,6]. As it is a known fact that stature varies from race to race[1,5]. Therefore area specific work has its own important. Looking into these facts the present study was conducted to find out the correlation between arm span and stature in a defined population.

## MATERIAL AND METHOD

A total number of 200 cases were studied which included 100 males and 100 females. These cases were undergraduate and postgraduate medical student of Rajasthan between the age group of 21-30 years. This age group was considered, as after 20 years of age almost all vertically placed long bones are ossified completely and no demonstrable growth in height is noticed

thereafter. Measurements were taken at fixed duration in a day to eliminate the discrepancies due to diurnal variation. Participants with any spinal and other skeletal abnormality of the limb were not included in study.

Stature is taken as standing height from tip of head (highest point of vertex) to toe in the erect posture when subject's head is positioned in the Frankfurt horizontal plane. Standing height was measured with the individual standing barefoot on the platform of the stadiometer. The participants had to put their feet together and move back until their heels touched the bottom of the stadiometer upright. Their buttocks and upper part of their back were in contact with the vertical board but their head did not have to touch the stadiometer. The movable headboard of stadiometer was brought into firm contact with the vertex with sufficient pressure to compress the hair.

Arm span is the horizontal distance between the tips of the middle fingers of both hands. In normal condition arm span is slightly more than stature. Arm span was measured using a calibrated flexible steel tape. Both arms were extended laterally parallel to the ground at shoulder level forming an angle of $90^0$ from trunk. The elbows and wrists were extended and the palms were facing directly forward. Then measurements were taken from the tip of the middle finger of the right hand to the tip of the middle finger of the left hand across the chest with the tape passing in front of the clavicles. Both stature and arm span measurements were taken in centimetres to the nearest 0.1 centimetre.

Statistical analysis was performed using Smith's Statistical Package (SSP-Version 2.80), MedCalc Version12.7.0.0, GraphPad Prism 4.01 for Windows and MS Excel. The p value less than 0.05 was considered as significant.

The correlation between stature and arm span was determined using simple correlation coefficient and their 95% confidence interval.

The mean correction values were obtained after substitution of stature from arm span. Similarly fixed multiplication factors were calculated as a mean of ratio of stature and arm span.

Then linear regression analyses were performed. Finally these relationships were plotted as scatter diagrams and regression lines. Prediction equations were determined from slope and intercept. Arm span was considered as the independent variable. Then the predicted stature of each subject was estimated from arm span by three different methods:

- By direct substitution of mean correction value from arm span (termed as $stat^{mcv}$);
- By dividing the arm span with the fixed multiplication factor based on ratio of stature and arm span (termed as $stat^{mf}$);
- By regression equation (termed as $stat^{reg}$).

Bland Altman plots are extensively used to evaluate the agreement among two different instruments or two measurements techniques. Actual measured stature ($stat^{act}$) which was considered as gold standard method, was compared with the predicted stature from all three methods ($stat^{mcv}$, $stat^{mf}$ and $stat^{reg}$). Bland Altman graphs were plotted and degrees of freedom were determined.

The mean difference is the estimated bias, and the SD of the differences measures the random fluctuations around this mean. If the differences are within mean ± 1.96 SD, the two methods may be used interchangeably.

The data obtained was analysed and best method was determined among three method to estimate stature or height from arm span.

**Table 1: Different values for estimating regression equation**

| | Coefficient | SE | 95%CL | T | P value |
|---|---|---|---|---|---|
| | | | **MALE** | | |
| **Intercept** | 38.8947 | 3.45 | 32.05 to 45.74 | 11.28 | <0.0001 |
| **Slope** | 0.7393 | 0.02 | 0.70 to 0.78 | 38.31 | <0.0001 |
| | **RSD=1.6261** | | **$R^2$=0.9374** | **n=100** | |
| | | | **FEMALE** | | |
| **Intercept** | 25.6380 | 3.58 | 81.54 to 32.74 | 7.17 | <0.0001 |
| **Slope** | 0.8149 | 0.022 | 0.77 to 0.86 | 36.91 | <0.0001 |
| | **RSD=1.5111** | | **$R^2$=0.9329** | **n=100** | |

**Table 2: Bland altman analysis to compare different methods of estimating height in all cases**

| BLAND ALTMAN ANALYSIS IN ALL CASES (n=200) | | | | | |
|---|---|---|---|---|---|
| **METHODS** | **Mean of difference (Bias)** | **S.D. of Bias** | **95% Limits of Agreement (positive)** | **95% Limits of Agreement (negative)** | **P value** |
| **$stat^{act}$ vs $stat^{mcv}$** | -1.1 E-014 | 2.90 | 5.7 | -5.7 | >0.99 |
| **$stat^{act}$ vs $stat^{mf}$** | -0.1 | 2.59 | 4.93 | -5.20 | 0.46 |
| **$stat^{act}$ vs $stat^{reg}$** | 0.0 | 1.59 | 3.12 | -3.12 | >0.99 |

mf= multiplication factor, mcv= mean correction value, reg=regression coefficient

## RESULTS

In the present study, mean arm span in Rajasthani adults was 178.47±8.47 cm in males and 161.86±6.88 cm in females while mean stature was 170.84±6.46 cm in male and 157.54±5.80 cm in female. The results of this study showed that the mean arm span measure exceeded stature measure in Rajasthani adults. Stature and arm span had a strong positive linear relation which was highly significant. In males and females correlation coefficients (r) were 0.968 and 0.966. Overall correlation coefficient was 0.984.

Mean Correction values (mcv) for male, female and overall were 7.6310, 4.3170 and 5.974 respectively while Multiplication factors (mf) were 0.9577, 0.9736 and 0.9657 respectively.

Regression equations which can be used in clinical and nonclinical settings to estimate the stature of Rajasthani adults are as following:

Male: Stature (in cm) = 38.8947+ 0.7393 arm span (in cm)

Female: Stature (in cm) = 25.6380 + 0.8149 arm span (in cm)

Overall: Stature (in cm) = 30.4161+ 0.7861 arm span (in cm)

The Bland Altman analysis of the results showed that the 95% limits of agreement were narrow and represents a good agreement between all methods. But this agreement was narrowest between $stat^{act}$ and $stat^{reg}$ and the scatter around the bias line was uniform. Thus regression method is the best method and these two methods may be used interchangeably.

**Figure 1: Bland Altman plot between $stat^{act}$ and $stat^{mcv}$**

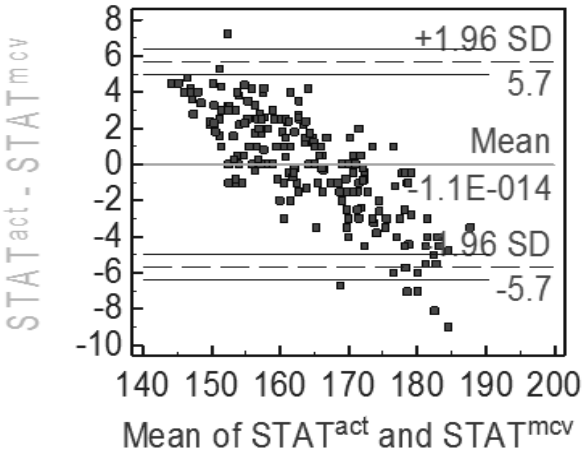



**Figure 2: Bland Altman plot between $stat^{act}$ and $stat^{mf}$**

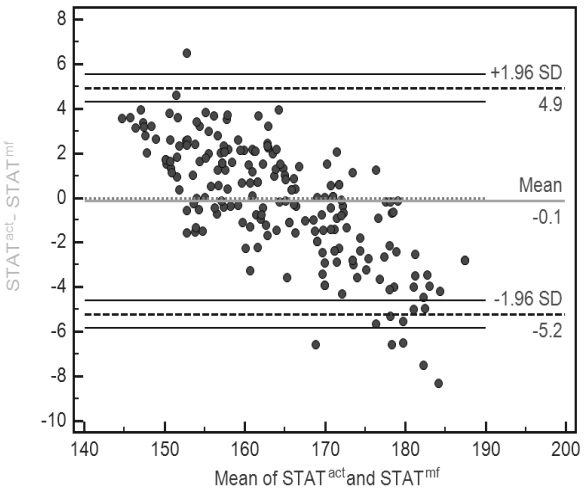
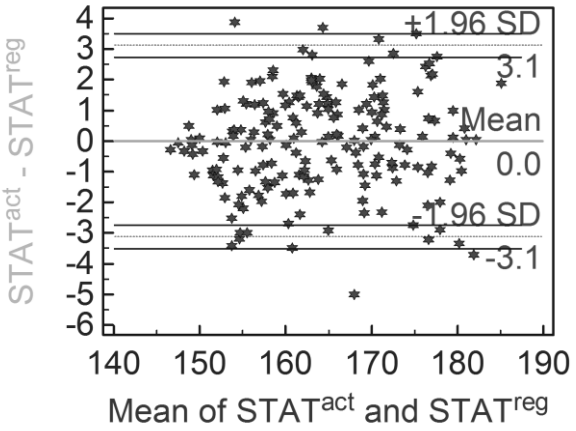



**Figure 3: Bland Altman plot between $stat^{act}$ and $stat^{reg}$**




## DISCUSSION

The estimation of height from various parameters has been done by many workers. M. C. Athwale[7] estimated height from length of forearm bones while Kate BR et al[8] estimated stature from lengths of femur and humerus by regression method and autometry. Stature as well as the association between arm span and stature vary from race to race, and therefore area specific work has its own importance (Daniel TG et al[1], Mohanty SP et al[5]). Steele MF et al[9] measured slight difference in correlation of arm-span and height for Black (0.852) and White (0.903) races.

The prediction of stature utilizing arm span measurement has been attempted by many authors using smaller samples (Steele MF et al[9], 1990; Kwok and Whitelaw[3], 1991; Aggarwal AN et al[10], 2000).

Age group included for present study was between 21-30 years. Other studies included cases with age (in years) between 20-49 (Daniel TG et al[1]), 25-45 (Samira Hossain et al[4]) and 20-29 (Mohanty SP et al[5]). Age was a significant factor in Caucasian males and females for Linderholm et al[11]. It was a significant factor for males only, whether Caucasians or Afro-Americans, for Parker JM et al[12]. This study reveal that knowing the age (in yrs.) gives essentially no information about stature (in cm) (r=0.088) (p=0.21). Similarly there is almost no correlation between age and stature (r= -0.078, p=0.27). These finding are consistent with Mohanty SP et al[5]. It was speculated by André Capderou et al[2] that the age has effect on the arm span equations but it was possibly a cohort effect.

In Nigerian adults (Daniel TG et al[1]) arm span exceeded stature in all the age groups of both genders. The mean difference between the stature and arm span was 4.4 ± 4.5 cm (t=14.24, p<.001) for women and 5.8 ± 6.2 cm (t=12.85, p<.001) for men. Gender difference between stature and arm span measurements was statistically significant (t=9.71, p<.001 and t=10.03, p<.001, for male and female respectively). These values of stature and arm span in male are comparatively lower than present study but in female mean values are slightly higher. Mohanty SP et al[5] observed that mean arm span was 159.14 cm (SD=7.06), which was also on average 2 cm more than standing height. In the study of Steele MF et al[9], arm span was nearly 8.3 cm more than height for blacks, whereas for whites, this difference was only 3.3 cm. In the present study arm span was nearly 2.5 cm more than height, which is near to that noted in the white population.

Daniel TG et al[1] observed a positive strong correlation between arm span and height (r=0.83, p<0.01). Mohanty SP et al[5]

observed that the correlations between sitting height, arm span and leg length were poor (r=0.56 and 0.29 respectively), while the correlations of arm span and leg length with standing height were good (r=0.82 and 0.84 respectively). Samira Hossain et al[4] (r=0.89, p=0.000) also showed significant positive correlation. Steele MF et al[9] reported correlations of arm span and height of 0.852 and 0.903 for black and white women respectively. The findings of this study are also consistent with other studies as arm span and stature have a strong positive linear relation via a firm linear rule. In both male (r=0.968, P<0.0001) and females (r=0.9666, p <0.0001) strong correlation has been observed.

In this study Multiplication factor was calculated for estimating stature from each arm span measurement as a ratio of stature/Arm-span. As mean arm span measure exceeded mean stature measure, this multiplication factor is less than one. Opposite fact appeared in study of André Capderou et al[2]. They described it in the form of a fixed ratio between arm span to measured height and this was more than one. Parker JM et al[12] observed that fixed Arm-span-to-height ratios may be used to estimate height with reasonable accuracy, but there were errors at extremes of stature. Aggarwal AN et al[10] observed that height obtained by substitution of arm span or estimation by ratio method resulted in similar errors in interpretation of spirometric data.

Bland Altman analysis was performed in very few studies. In this study, this analysis was performed to examine the agreement between actual measured stature ($stat^{act}$) and different estimated stature: a) $stat^{mcv}$ by using mean correction value (mcv); b) $stat^{mf}$ from multiplication method; c) $stat^{reg}$ by using regression equation. Results are shown in table 2 and graphs 1-3.

Actual measured stature ($stat^{act}$) was considered as gold standard method. In present study, Bland Altman analysis for $stat^{act}$ vs $stat^{mcv}$ and $stat^{act}$ vs $stat^{mf}$ showed that there was an underestimation of height and a wider limits of agreement in both cases. This finding is consistent with Chhabra et al[6], who observed that the mean difference between FVC-$Ht_{act}$ and FVC-$Ht_{as}$ was large with wide limits of agreement in both the groups.

In present study, the mean difference between $stat^{act}$ and $stat^{reg}$ was 0.0 and the scatter around the bias line was uniform (graph no. 11, 14 and 17). The 95% limits of agreement were narrower and represented a good agreement between two methods. Again, these finding are consistent with the observations of Chhabra et al[6], where the mean difference between FVC-$Ht_{act}$ and FVC-$Ht_{est}$ and between FVC-$Ht_{act}$ and FVC-$Ht_{pred}$ was smaller in both the groups. Aggarwal AN et al[10] observed that height obtained by substitution of arm span or estimation by ratio method resulted in similar errors in interpretation of spirometric data.

## CONCLUSION

Stature is a very important anthropometric tool in the clinical and non-clinical field and should be measured directly according to standard methods. If direct measurement is not possible than arm span is the most reliable surrogate method for predicting the stature of an individual. It is useful in predicting age-related loss in stature and in identifying individuals with disproportionate growth abnormalities and skeletal dysplasia. It can also be of use in finding out the alterations in the height of an individual that may occur due to progressive deformities of the spine and following surgical correction of spinal deformities. Strong correlation between arm span and stature in Rajasthani adults will be of practical use in medico legal investigations and in anthropometry. Present study used arm span as a surrogate method for the estimation of stature.

Among three methods, estimation of stature by regression equation is the best method. Regression equations which can be used in clinical and nonclinical settings to estimate the stature of Rajasthani adults are as following:

Male: stature (in cm) = 38.8947+ 0.7393 arm span (in cm)
Female: stature (in cm) = 25.6380 + 0.8149 arm span (in cm)
Overall: stature (in cm) = 30.4161+ 0.7861 arm span (in cm)

## RECOMMENDATION

The sample size was small and the convenience sampling had to be applied because the study was done on such a group of people where a sampling frame could not be rigidly constructed. The results of the present study will provide baseline information. However, it was proved statistically that correlation between stature and arm span and derived regression equations have highly significant p values. Thus a study on a large sample defining Rajasthani population can be set up keeping work and data of this study as basic guideline.

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