

STATISTICAL ESTIMATION OF HEIGHT FROM ARM SPAN IN NORTH INDIAN SUBJECTS

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Abstract : We measured height and arm span of 400 males and 231 female subjects between 16-83 years of age. Arm span exceeded height in 82.6% subjects. Mean height to arm span ratio was 0.9711 and 0.9816 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.

Key words : arm span height regression equation

INTRODUCTION

Height is one important body measurement in human beings. It is used to assess longitudinal growth in children and adolescents, calculate body surface area, and predict normal body functions. Another important anthropometric parameter used for various predictions is the arm span. The relationship between height and arm span is important in the diagnosis of disorders of connective tissue such as Marfan's syndrome. Several investigations in the past have looked for a correlation between height and arm span (1-5). Such correlation is useful to predict height in subjects in whom it cannot be reliably measured due to debility or structural defects (1-3). Like most other anthropometric measurements, height and arm span relationship is likely

to differ in various ethnic groups (5). It is therefore important to study this relationship in native populations. The present study was designed to evaluate the relationship between arm span and height in North Indians for a more accurate in estimation of height in subjects in whom height is difficult to measure.

METHODS

Healthy individuals accompanying patients referred to the Respiratory laboratory at our hospital for lung function studies were included in this study. Subjects aged 15 years or less were excluded. Subjects in whom height could not be measured accurately due to debility or structural defects were excluded. Similarly, patients with chest or upper limb

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deformities that made arm span measurement difficult, and those with medical disorders known to alter body proportions such as Marfan's syndrome, acromegaly, dwarfism and kyphoscoliosis were excluded. A total of 631 subjects were ultimately chosen during a four month study period, after exclusion of 76 persons based on one or more of the above criteria. Informed consent was taken from all eligible subjects prior to their inclusion in the study.

The study involved comparison of two measures of height (actual standing height and height estimated from arm span) for each subject. Therefore the minimum sample size was determined from the standard deviation of the differences between paired values at a given significance and power of study, using the formula for 'paired' data (6)

$$n = \left[\frac{(Z_{2\alpha} + Z_{2\beta}) \sigma}{\delta} \right]^2$$

where n is the minimum number of pairs, $Z_{2\alpha}$ is the standardized normal deviate exceeded with probability 2α ($2\alpha = 0.05$ in the present estimation), $Z_{2\beta}$ is the standardized normal deviate associated with the power of study (power 0.95 in the present estimation), σ is the standard deviation of difference in true height and height estimated from arm span measurements in adult population, and δ is the specified mean difference between the two sets of observations for height (actual height and height estimated from arm span). Since there is no available Indian estimate of the value of σ , we used a value of 3.51 cm

for males and 3.60 cm for females based on data on healthy individuals from a previous study (3). Using these values and specifying a mean difference of more than 1 cm between the actual and predicted heights as significant at 95% power, we estimated a sample size of 190 males and 200 females for this study. A much larger population was actually studied to further reduce the margin of error.

Height was defined as the vertical distance from the heels to the vertex in a subject standing erect. Standing height was 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 were then cupped and gentle upward traction applied till the lower orbital margin was level with the external auditory meatus. A horizontal rigid sliding ruler was then used to read the height directly from the scale on the stadiometer. Arm span was measured between the tips of both middle fingers of horizontally abducted and maximally outstretched hands and fingers, with the subjects standing and facing the wall. Both measurements were taken to the nearest completed centimetre (cm).

Data analysis was carried out using the statistical program SPSS (6.0) for Windows. Mean and standard deviation (SD) was calculated for all the variables studied. Comparisons between groups were carried out using Students t-test and one way analysis of variance (ANOVA). Height to arm span ratios (HAR), as well as regression equations, were derived to aid prediction of height from arm span.

Statistical and graphical analysis was applied to both these models to determine their suitability for estimating height in the population studied.

RESULTS

The study included 400 male and 231 female subjects with age range of 16–83 years (Table I). Subjects were residents of Himachal Pradesh (167, 26.5%), Punjab (127, 20.1%), Haryana (116, 18.4%), Chandigarh (105, 16.6%), Uttar Pradesh (102, 16.2%) or Jammu and Kashmir (14, 2.2%). The mean height and arm span measurements were 170.5 ± 6.3 cm and 175.7 ± 7.4 cm for males and 157.8 ± 6.3 cm and 160.9 ± 7.2 cm for females respectively.

have no apparent medical disorder. The mean difference was 4.4 ± 4.3 cm and the difference was more than 8 cm in 115 subjects (19.2%). Mean HAR for the entire study population was 0.9749 ± 0.0249 . The differences between height and arm span measurements, as well as HAR, were significantly different among the two sexes ($P < 0.01$). Subgroup analyses showed these differences to be significant mainly in the younger population aged 45 years or less (Table I). Although male subjects showed a lower HAR in the elderly population (Table I), there was no significant correlation between HAR and age (Pearson's correlation coefficients -0.0648 and -0.1188 for male and female subjects respectively; p not significant for either group). HAR was not significantly

TABLE I : Height : arm span ratio (HAR) and difference between arm span and height measurements for various age groups (results as mean and standard deviation).

| Age (years) | Males | | | Females | | |
|-------------|------------|-------------------|-----------------|------------|-----------------|-----------------|
| | Number | HAR | Difference (cm) | Number | HAR | Difference (cm) |
| 16–25 | 67 (16.8%) | 0.9750 (0.0235)* | 4.5 (4.2)** | 40 (17.3%) | 0.9871 (0.0234) | 2.1 (3.7) |
| 26–35 | 84 (21.0%) | 0.9693 (0.0190)** | 5.5 (3.4)** | 58 (25.1%) | 0.9823 (0.0256) | 3.0 (4.2) |
| 36–45 | 88 (22.0%) | 0.9732 (0.0275)* | 4.8 (4.9)** | 67 (29.0%) | 0.9824 (0.0220) | 2.9 (3.6) |
| 46–55 | 78 (19.5%) | 0.9701 (0.0274) | 5.4 (4.9) | 42 (18.2%) | 0.9759 (0.0249) | 4.0 (4.0) |
| 56–65 | 54 (13.5%) | 0.9723 (0.0250) | 4.9 (4.4) | 17 (7.4%) | 0.9784 (0.0260) | 3.6 (4.2) |
| 66–75 | 25 (6.3%) | 0.9604 (0.0227) | 7.0 (4.2)* | 7 (3.0%) | 0.9789 (0.0177) | 3.4 (2.9) |
| > 75 | 4 (1.0%) | 0.9626 (0.0117) | 6.5 (2.1) | – | – | – |
| Total | 400 | 0.9711 (0.0245)** | 5.2 (4.4)** | 231 | 0.9816 (0.0239) | 3.0 (3.9) |

* $P < 0.05$; ** $P < 0.01$

In the total study population, arm span measurements were more than height in 421 (82.6%), less than height in 74 (11.7%), and equal to height in 36 (5.7%) subjects. The maximal difference recorded was 17 cm in one subject. He was examined and found to

different for either male or female subjects when subjects older than 65 years were compared with younger subjects. ANOVA model also did not show any significant differences in HAR among the various age groups for either sex.

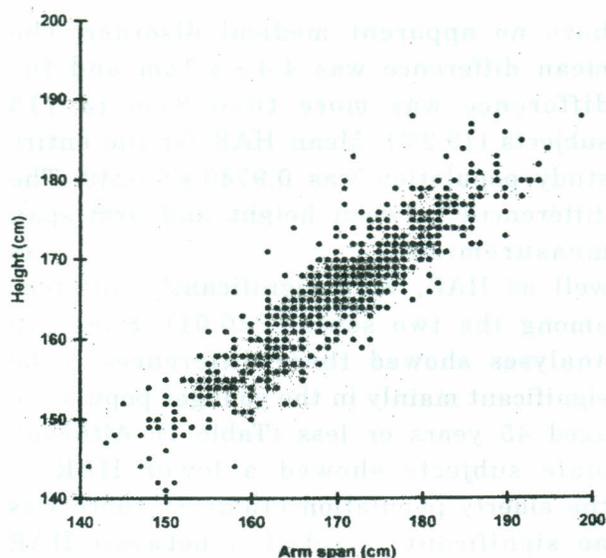


Fig. 1: Scatter diagram showing relationship between height and arm span in the entire study population.

A graphical analysis revealed height to be nearly linearly related to arm span in the study population (Fig. 1). Therefore linear regression equations were generated for prediction of height from arm span for either sex and for the study population as a whole (Table II). Residual analyses of these equations revealed that the standardized residuals, obtained by dividing the residual (i.e. the difference between the actual and the predicted height using regression equations) with its estimate of standard error, were in a normal distribution for all equations. The slope of a plot of residuals versus the predictor arm

TABLE II: Regression equations for prediction of height (cm) from arm span (cm).

| Sex | Regression equation | r^2 | RSD |
|---------|------------------------------------|--------|------|
| overall | height = 0.776 (arm span) + 33.837 | 0.8226 | 3.68 |
| males | height = 0.681 (arm span) + 50.818 | 0.6473 | 3.71 |
| females | height = 0.731 (arm span) + 40.233 | 0.7094 | 3.38 |

RSD residual standard deviation

span using equation 1 is zero, indicating no interdependence between variables (Fig. 2). Similar results were also obtained for equations 2 and 3.

Residual plots were also obtained for differences between the actual and the estimated height using fixed ratios (predicted height = arm span \times HAR). The plot for the entire study population using a HAR of 0.9749 has a slope of -0.199 (Fig. 2). Corresponding plots were also obtained for males and female populations separately using HAR of 0.9711 and 0.9816 respectively (Table I); both had finite slopes (-0.2898 and -0.2506 respectively).

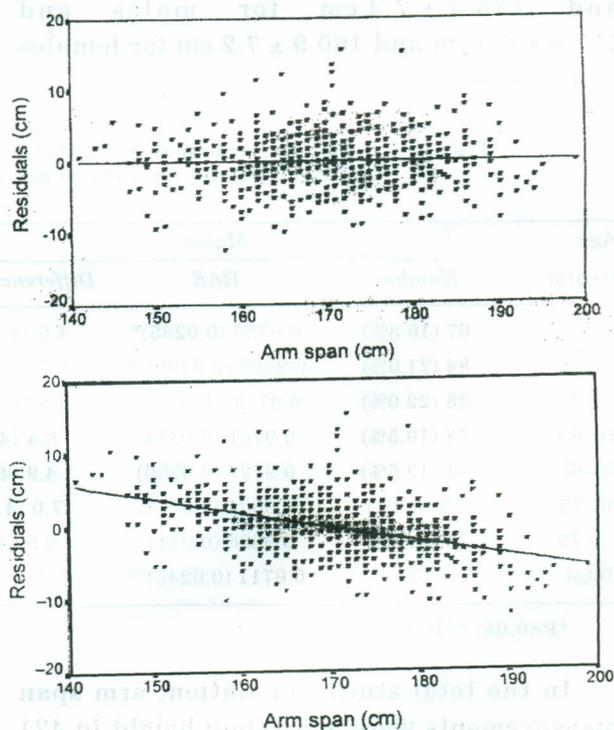


Fig. 2: (Top) Residual analysis for the entire study population using regression equation I. The plot between residuals (difference between actual and predicted height) and arm spans has a zero slope. (Bottom) Residual analysis for the entire study population using a fixed HAR of 0.9749. The plot between residuals and arm spans has a finite slope of -0.199 .

Multiple linear regression analysis using arm span and age as independent variables showed that these equations could only explain a further 0.47%, 0.46% and 0.14% of the variance respectively as compared to equations 1, 2 and 3 (Table II).

DISCUSSION

The earliest documented observation that man can be drawn in a square (and in a circle) was made by the Roman architect Vitruvius, thereby indicating that arm span was equal to height in the perfect human being (7). Until the 19th century, the equality of arm span and height in Vitruvian man was largely an artistic and philosophical concept. When measurement replaced impression, this equality was found to be uncommon, with arm span more often being greater than height. The English sculptor Bonomi first designed an instrument to measure height and breadth in man (8). His measurements in 84 subjects revealed arm span to be greater than height in 54, less than height in 24, and equal to height in only 6. Extensive measurements of arm span and height have only been done in this century (9-11). Several studies have confirmed that arm span exceeds height in the vast majority of normal individuals (59 to 85% in various reports) (8-10). The magnitude of this difference is usually small, though Buist reports a difference of more than 3 inches in 12% cases (this cut-off value is taken as an indicator of Marfan's syndrome), with extremes of up to more than 6 inches (10). Our findings include arm span in excess of height in 82.6% subjects, with a mean of 4.4 (± 4.3) cm. These are in accordance with earlier reports. Arm span exceeded height by more than 8 cm in 19.2%

of our subjects. This might be related to ethnic variations.

Subjects included in the study were attendants of patients referred to us for spirometry and hence formed a sample of convenience. However, any sample bias is unlikely to have been introduced as all eligible subjects were enrolled consecutively. Since these subjects had no apparent medical disorder, they represent the healthy general population. These subjects were drawn from several states in North India, and the relationship derived between height and arm span can, therefore, be extrapolated to and used for the general population residing in this region.

The r^2 values for the regression equations, though less than optimum, still show that a large proportion of variance in the distribution is adequately explained by these equations. The residual standard deviation (RSD) obtained in this study is similar to an earlier estimate in healthy individuals (3). The error in prediction, when these equations are used in the general population, can be estimated from the 95% confidence interval, which is described as the value of the dependent variable derived from the regression equation ± 1.96 RSD. Accordingly, the error in prediction will be less than ± 7.3 and ± 6.6 cm in males and females respectively in 95% instances (Table II). Such error is unlikely to have a significant impact in most clinical situations.

The wide age range of subjects included in the study makes these regression equations suitable for application in a large majority of adult population (Table I). The

use of age as an additional predictor variable explained a very small amount of variance in these equations, but this increment is not of much practical importance. Similarly, we have not found any significant correlation between age and HAR. Theoretically, this ratio may decrease as people lose height with advancing age due to degenerative changes in the spine, whereas the arm span remains unchanged. Linderholm found this to be true, but other reports have not established a similar relationship (2-4). Overall we can conclude that, in the population studied, age is not a major predictor for estimation of height from arm span.

The residual plots displayed in Fig 2 indicate that these regression equations can be used to predict height at the entire range of arm spans with good precision. The same was not true when fixed ratios were used. The slope of the residual plots, when this method was used, indicated that at extremes of arm spans found in the study, the ratio method either underestimated (at smaller arm spans) or overestimated (at larger arm spans) height as compared to actual height. Although the use of a fixed ratio is simpler, it provides a less acceptable method of estimating height when compared with the regression equations, especially at extremes of height.

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