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# ASSESSMENT OF UPPER LIMB DIMENSIONS AND ITS ASSOCIATION WITH AGE, SEX, HEIGHT, WEIGHT, AND BODY MASS INDEX AMONG ADULTS: A COMMUNITY BASED CROSS-SECTIONAL STUDY

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ABSTRACT

**Background:** Assessment of the upper limb dimensions provides information quantitatively regarding body proportions and has its application in various fields like - anatomy, forensic anthropology, ergonomics, and clinical practices. Most of the study demonstrated association of upper limb dimensions and stature and its sex related differences. The present study assessed relationships of the age, sex, anthropometric and anthropometric index with selected upper-limb dimensions.

**Materials and Methods:** A cross-sectional study was conducted around Government Medical College, Badaun among 300 adults aged 21-35 years and were selected by convenience sampling and among these 150 were males and 150 were females. Participants were distributed equally into three age groups. Height, weight, body mass index, arm span and bilateral upper limb dimensions were recorded. Descriptive statistics, independent t-tests, one-way analysis of variance, paired-sample t-tests and Pearson correlation were used as a part of analysis for this specific study and was did on Jamovi 2.7.31.

**Results:** The calculated mean weight, height and body mass index were 62.93±10.70 kg, 165.22±8.34 cm and 22.96±2.90 kg/m² respectively. For all assessed upper limb dimensions female had significantly lower values than males ($p < 0.001$), whereas there were no significant differences observed across age groups and in right-left upper limb measurement differences. The height and weight showed significant positive correlations with all measured upper limb dimensions, and association with body mass index were weak.

**Conclusion:** Upper limb dimensions showed marked sex related variation whereas variation across the adult age groups were narrowed. Height demonstrates the strongest relation with linear upper limb dimensions while body mass index had weak associations.

**Keywords:** Anthropometry, Upper limb, Hand, Body Height, Body Mass Index.

## INTRODUCTION

The systematic quantitative assessment of human body dimensions and proportions were done by anthropometry. Anthropometric measurements can be use in fields of anatomy, physical anthropology, forensic identification, ergonomics, rehabilitation and clinical assessment. The upper limb is most suitable for anthropometric investigation because many of the dimensions can be measured externally using identifiable anatomical landmarks.[1,2]

Segmental lengths, hand dimensions and circumferential measurements were included in upper limb anthropometry and these variable shows different aspects of body morphology. Skeletal proportions and overall body size are closely related to linear dimensions whereas the muscles and soft tissues influence the circumferential measurements.

Hand dimensions are applicable to ergonomic design because the interaction between an individual and hand-held equipment can be guide by dimensions of the hand.[1,3,4]

Extensive research has scrutinized the association between upper limb dimensions and body stature. A logical basis is that body segments maintain a predictable relationship with overall height of body and can therefore provide stature estimates. Such measurements keep their usefulness in forensic anthropology when the complete bodies or intact skeletal remains are not available.[5,6]

Goyal et al. estimated human stature among North Indian population by palpating percutaneous landmarks of upper limb; humerus, radius and ulna lengths were measured and significant positive relation with stature had been demonstrated; while the multiple linear regression showed that the ulna length was most consistent predictor of stature.[7] Jha et al. did gender based estimation of physical stature by using percutaneous lengths of long bones in a North Indian population, while Singla et al. investigated percutaneous humeral length for stature estimation.[8,9] Sarma et al. demonstrated strong correlations between ulnar length of adult Khasi population and their stature.[10] Supare et al. reported that the arm span and stature among medical students from Maharashtra had strong correlation with correlation coefficient of 0.90 in females and 0.89 in males.[11] Rastogi et al. showed significant relationships between hand dimensions and stature of North and South Indian adults.[12]

Hand dimensions also showed sexual dimorphism. Kanchan et al. found significant sex related differences in hand dimensions while hand breath was the most useful discriminatory characteristics by studying 500 hands from North and South Indian populations.[13] Krishan et al. demonstrated the presence of sexual dimorphism in hand and foot dimensions of North Indian populations.[14] Many of the Indian studies have demonstrated significant sex related differences in hand dimensions.[15,16]

Human body is broadly bilateral symmetrical but sometimes differences may occur because of habitual activity, functional dominance or individual variation. Rastogi et al. observed that there are differences in right-left hand dimensions, whereas the other studies had stated insignificant variation.12–14 This variation supports the need of assessing both sides of upper limb when taking anthropometry.

The relationship of upper limb dimensions with general body size variables like – weight, height and body mass index (BMI) has gained less attention than stature prediction. Weight reflects the skeletal and soft tissue mass, height had strong association with linear upper limb dimensions and these both reflects longitudinal skeletal growth and overall body proportions while the BMI is derived index and not represents skeletal size. Aim of this study was to assess various upper limb anthropometric dimensions among adults and examine the differences according to sex and age, right-left asymmetry and its association with weight, height and BMI.

## MATERIALS AND METHODS

**Study design and setting:** A cross-sectional study conducted in community around Government Medical College, Badaun, Uttar Pradesh, India, from June 2026 to July 2026 among adult aged 21-35 years.

**Sample size and Sampling:** Sample size was calculated by using the smallest correlation reported by Goyal et al. ($r = 0.2517$) as a conservative effect size, with two-sided $\alpha = 0.05$ and 80% power, so the required sample size for the primary Pearson correlation analysis is 122 participants.[7] The secondary objective of comparing upper limb dimensions by sex will requires a larger sample size so, using $\sigma = 2.5$ cm and a minimum detectable difference $\Delta = 1.0$ cm, the two-sample formula outputs 98 participants per sex means total 196. With 10% non-response rate this is increases to ≈218. For the adequate power in sex comparisons, age-stratified analyses, right-left asymmetry testing and to provide a practical recruitment buffer, we will take total 300 participants (150 males and 150 females) and this sample was equally distributed across the three predefined age groups that is 21-25 years, 26-30 years and 31-35 years and in every age groups there were 50 males and 50 females.

**Inclusion and Exclusion criteria**

Adults aged 21-35 years residing in study area and given consent to participate in study. Individuals with upper limb deformity, upper limb amputation, any injury in upper limb or any such condition which preventing accurate anthropometric assessment and participants not given consent were not enrolled in study.

**Data Collection:** Data collected by using semi-structured questionnaires that including age-group, gender, residence and hand dominance. Weight, height and BMI were recorded. Bilateral upper limb measurements were also done, and it includes upper arm length, forearm length, total upper limb length, hand length, hand breadth, mid-upper arm circumference (MUAC), forearm circumference and wrist circumference.

**Statistical Analysis:** Mean ± standard deviation (SD) used for analysis of continuous variables whereas the categorical were presented by frequency with percentage. Independent-samples t-tests were applied to compare the upper limb dimensions between females and males. For comparing among the age groups one-way analysis of variance (ANOVA) was used while paired-samples t-tests were applied to compare right and left side measurements. Assessment with Pearson correlation coefficients to assess the relationships between upper limb dimensions and weight, height and BMI assessed by. p value $<0.05$ was considered significant statistically.

## RESULTS

The detail of 300 adults according to age groups, gender, residence and hand dominance had done. Total participants were distributed equally, that means 100 participants in each age group of 21-25, 26-30 and 31-35 years respectively and for gender 150 males and 150 females, most of the participants were from rural areas 172 (57.3%) with right hand dominance among 277 (92.3%) participants. [Table 1]

**Table 1: Details of Participants:**

| Characteristics | | Participants, n (%) |
|---|---|---|
| Age Groups (years) | 21-25 | 100 (33.3) |
| | 26-30 | 100 (33.3) |
| | 31-35 | 100 (33.3) |
| Gender | Female | 150 (50) |
| | Male | 150 (50) |
| Residence | Rural | 128 (42.7) |
| | Urban | 172 (57.3) |
| Dominant hand | Left | 23 (7.7) |
| | Right | 277 (92.3) |

The general anthropometric and upper limb measurements of all 300 participants done and the mean weight was 62.93 ± 10.70 kg while the mean height recorded was 165.22 ± 8.34 cm and the calculated mean BMI was 22.96 ± 2.90 kg/m². The mean arm span was 165.27 ± 9.19 cm and mean total upper limb length was 54.58 ± 3.07 cm. [Table 2]

**Table 2: General anthropometric and upper limb measurements:**

| Characteristic | Mean (SD) |
|---|---|
| Height (cm) | 165.22 (8.34) |
| Weight (kg) | 62.93 (10.70) |
| BMI (kg/m²) | 22.96 (2.90) |
| Right Upper Arm Length (cm) | 29.77 (1.80) |
| Left Upper Arm Length (cm) | 29.78 (1.81) |
| Right Forearm Length (cm) | 24.79 (1.45) |
| Left Forearm Length (cm) | 24.82 (1.46) |
| Right Total Upper Limb Length (cm) | 54.58 (3.07) |
| Left Total Upper Limb Length (cm) | 54.58 (3.07) |
| Right Hand Length (cm) | 18.23 (1.08) |
| Left Hand Length (cm) | 18.25 (1.08) |
| Right Hand Breadth (cm) | 7.88 (0.60) |
| Left Hand Breadth (cm) | 7.87 (0.59) |
| Right MUAC (cm) | 27.55 (2.45) |
| Left MUAC (cm) | 27.54 (2.45) |
| Right Forearm Circumference (cm) | 24.41 (2.09) |
| Left Forearm Circumference (cm) | 24.41 (2.06) |
| Right Wrist Circumference (cm) | 16.15 (1.27) |
| Left Wrist Circumference (cm) | 16.14 (1.27) |
| Arm Span (cm) | 165.27 (9.19) |

On doing comparison of selected upper limb dimensions and gender it is observed significant gender related differences among all assessed upper limb dimensions. Males had significantly greater values than females for every assessed upper limb dimension and all comparisons showed p <0.001. The largest differences among the linear upper limb measurements were observed in total upper limb length and the mean male-female differences for right and left was 3.6 cm and 3.5 cm respectively. Measured hand breadth was differed by 0.85 cm on both side whereas the wrist circumference showing differences of 1.9 cm between males and females. Arm span was significantly smaller in females (159.46 ± 6.85 cm) than males (171.09 ± 7.39 cm) with p-value <0.001. [Table 3]

**Table 3: Comparison between measured upper limb dimensions and gender:**

| Characteristic | Male Mean (SD) | Female Mean (SD) | Differences (Male – Female) | 95% CI | p-value |
|---|---|---|---|---|---|
| Right Upper Arm Length (cm) | 30.78 (1.60) | 28.75 (1.37) | 2 | 1.7, 2.4 | <0.001 |
| Left Upper Arm Length (cm) | 30.81 (1.58) | 28.74 (1.37) | 2.1 | 1.7, 2.4 | <0.001 |
| Right Forearm Length (cm) | 25.58 (1.26) | 24.01 (1.17) | 1.6 | 1.3, 1.8 | <0.001 |
| Left Forearm Length (cm) | 25.61 (1.26) | 24.02 (1.18) | 1.6 | 1.3, 1.9 | <0.001 |
| Right Total Upper Limb Length (cm) | 56.39 (2.65) | 52.77 (2.30) | 3.6 | 3.1, 4.2 | <0.001 |
| Left Total Upper Limb Length (cm) | 56.38 (2.62) | 52.79 (2.35) | 3.5 | 3.0, 4.2 | <0.001 |
| Right Hand Length (cm) | 19.00 (0.81) | 17.46 (0.70) | 1.5 | 1.4, 1.7 | <0.001 |
| Left Hand Length (cm) | 19.03 (0.80) | 17.47 (0.70) | 1.6 | 1.4, 1.7 | <0.001 |
| Right Hand Breadth (cm) | 8.30 (0.43) | 7.45 (0.42) | 0.85 | 0.75, 0.94 | <0.001 |

| | | | | | |
|---|---|---|---|---|---|
| Left Hand Breadth (cm) | 8.30 (0.41) | 7.44 (0.41) | 0.85 | 0.76, 0.95 | <0.001 |
| Right MUAC (cm) | 28.23 (2.38) | 26.87 (2.34) | 1.4 | 0.82, 1.9 | <0.001 |
| Left MUAC (cm) | 28.21 (2.37) | 26.86 (2.35) | 1.4 | 0.82, 1.9 | <0.001 |
| Right Forearm Circumference (cm) | 25.30 (1.90) | 23.52 (1.88) | 1.8 | 1.4, 2.2 | <0.001 |
| Left Forearm Circumference (cm) | 25.30 (1.87) | 23.52 (1.85) | 1.8 | 1.4, 2.2 | <0.001 |
| Right Wrist Circumference (cm) | 17.12 (0.86) | 15.18 (0.79) | 1.9 | 1.8, 2.1 | <0.001 |
| Left Wrist Circumference (cm) | 17.11 (0.86) | 15.18 (0.80) | 1.9 | 1.7, 2.1 | <0.001 |
| Arm Span (cm) | 171.09 (7.39) | 159.46 (6.85) | 12 | 10, 13 | <0.001 |

{Independent-samples t-tests done to compare among gender}

In respect to all three age groups no statistically significant differences were found for any of the assessed upper limb dimensions. The mean values of upper arm length, forearm length, hand dimensions, MUAC, total upper limb length and circumferences measurement were comparable across the three age groups while the arm span not differ significantly (p = 0.85) between the age groups. [Table 4]

**Table 4: Comparison of measured upper limb dimensions and age groups:**

| Characteristic | Mean (SD) 21 to 25 years | Mean (SD) 26 to 30 years | Mean (SD) 31 to 35 years | p-value |
|---|---|---|---|---|
| Right Upper Arm Length (cm) | 29.68 (1.78) | 29.79 (1.90) | 29.83 (1.73) | 0.82 |
| Left Upper Arm Length (cm) | 29.71 (1.80) | 29.77 (1.88) | 29.85 (1.76) | 0.85 |
| Right Forearm Length (cm) | 24.83 (1.49) | 24.81 (1.46) | 24.74 (1.39) | 0.91 |
| Left Forearm Length (cm) | 24.85 (1.48) | 24.82 (1.46) | 24.78 (1.44) | 0.94 |
| Right Total Upper Limb Length (cm) | 54.55 (3.05) | 54.60 (3.17) | 54.59 (3.01) | >0.99 |
| Left Total Upper Limb Length (cm) | 54.54 (3.08) | 54.61 (3.14) | 54.60 (3.00) | 0.98 |
| Right Hand Length (cm) | 18.22 (1.09) | 18.25 (1.02) | 18.23 (1.14) | 0.99 |
| Left Hand Length (cm) | 18.23 (1.11) | 18.28 (0.99) | 18.24 (1.15) | 0.94 |
| Right Hand Breadth (cm) | 7.86 (0.58) | 7.90 (0.64) | 7.87 (0.59) | 0.88 |
| Left Hand Breadth (cm) | 7.86 (0.57) | 7.89 (0.62) | 7.85 (0.59) | 0.89 |
| Right MUAC (cm) | 27.52 (2.56) | 27.49 (2.19) | 27.63 (2.61) | 0.92 |
| Left MUAC (cm) | 27.48 (2.53) | 27.50 (2.17) | 27.63 (2.65) | 0.9 |
| Right Forearm Circumference(cm) | 24.55 (2.18) | 24.38 (1.87) | 24.30 (2.21) | 0.7 |
| Left Forearm Circumference (cm) | 24.55 (2.12) | 24.40 (1.85) | 24.27 (2.21) | 0.67 |
| Right Wrist Circumference (cm) | 16.22 (1.36) | 16.11 (1.29) | 16.11 (1.18) | 0.81 |
| Left Wrist Circumference (cm) | 16.21 (1.36) | 16.13 (1.30) | 16.10 (1.17) | 0.83 |
| Arm Span (cm) | 165.68 (8.92) | 165.12 (9.67) | 165.01 (9.05) | 0.85 |

{ANOVA was use to compare among age groups}

There were no statistically significant right-left differences for any measured upper limb dimensions (all p >0.05). There is substantial bilateral symmetry between right side and left side upper limb, it can correlate by small mean differences and confidence intervals crossing zero. [Table 5]

**Table 5: Comparison between Right and Left side upper limb measurements:**

| Characteristic | Right | | Left | | Mean differences | 95% CI | | p-value |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Right - Left | Lower | Upper | |
| Upper Arm Length (cm) | 29.77 | 1.8 | 29.77 | 1.809 | -0.00933 | -0.049 | 0.030 | 0.648 |
| Forearm Length (cm) | 24.79 | 1.446 | 24.82 | 1.457 | -0.027 | -0.063 | 0.0092 | 0.144 |
| Total Upper Limb Length (cm) | 54.58 | 3.069 | 54.58 | 3.067 | -0.00267 | -0.052 | 0.0467 | 0.915 |
| Hand Length (cm) | 18.23 | 1.082 | 18.25 | 1.082 | -0.017 | -0.038 | 0.0042 | 0.116 |
| Hand Breadth (cm) | 7.88 | 0.6 | 7.87 | 0.593 | 0.00733 | -0.006 | 0.0212 | 0.3 |
| MUAC (cm) | 27.55 | 2.452 | 27.54 | 2.45 | 0.011 | -0.018 | 0.0401 | 0.458 |
| Forearm Circumference(cm) | 24.41 | 2.089 | 24.41 | 2.06 | 0.00267 | -0.023 | 0.0283 | 0.838 |
| Wrist Circumference (cm) | 16.15 | 1.274 | 16.14 | 1.275 | 0.00167 | -0.011 | 0.0146 | 0.801 |

{paired-samples t-tests were used for comparison of right and left sided measurements}

The height demonstrated significant positive correlations with all measured upper limb dimensions (p <0.001) and the strongest was found among height and arm span (r = 0.898) and this further followed by right (r = 0.879) and left (r = 0.870) total upper limb length. Strong correlations were observed for forearm and upper arm length of right and left side (r = 0.811 - 0.821), while hand dimensions showing moderate correlations (r = 0.499 - 0.525). Correlation between weight and upper limb dimensions were significant statistically and positive for all taken measurements and strongest was found with arm span (r = 0.614), total upper limb length (r = 0.584 - 0.587) and length of forearm (r = 0.569 - 0.583). The BMI showed weak

associations and statistically significant correlations was observed only with forearm length of right side (r = 0.133, p = 0.021) and hand length of left side (r = 0.122, p = 0.035). [Table 6]

**Table 6: Correlation of measured upper limb dimensions with height, weight and BMI:**

| Characteristic | Height (r) | p-value | Weight (r) | p-value | BMI (r) | p-value |
|---|---|---|---|---|---|---|
| Right Upper Arm Length (cm) | 0.811 | <.001 | 0.524 | <.001 | 0.054 | 0.354 |
| Left Upper Arm Length (cm) | 0.816 | <.001 | 0.525 | <.001 | 0.051 | 0.376 |
| Right Forearm Length (cm) | 0.816 | <.001 | 0.583 | <.001 | 0.133 | 0.021 |
| Left Forearm Length (cm) | 0.821 | <.001 | 0.569 | <.001 | 0.111 | 0.055 |
| Right Total Upper Limb Length (cm) | 0.879 | <.001 | 0.584 | <.001 | 0.082 | 0.155 |
| Left Total Upper Limb Length (cm) | 0.870 | <.001 | 0.587 | <.001 | 0.094 | 0.104 |
| Right Hand Length (cm) | 0.513 | <.001 | 0.392 | <.001 | 0.11 | 0.057 |
| Left Hand Length (cm) | 0.525 | <.001 | 0.408 | <.001 | 0.122 | 0.035 |
| Right Hand Breadth (cm) | 0.510 | <.001 | 0.368 | <.001 | 0.095 | 0.1 |
| Left Hand Breadth (cm) | 0.499 | <.001 | 0.361 | <.001 | 0.095 | 0.102 |
| Right MUAC (cm) | 0.248 | <.001 | 0.173 | 0.003 | 0.034 | 0.559 |
| Left MUAC (cm) | 0.243 | <.001 | 0.172 | 0.003 | 0.037 | 0.527 |
| Right Forearm Circumference(cm) | 0.248 | <.001 | 0.160 | 0.005 | 0.014 | 0.805 |
| Left Forearm Circumference (cm) | 0.254 | <.001 | 0.166 | 0.004 | 0.018 | 0.758 |
| Right Wrist Circumference (cm) | 0.547 | <.001 | 0.381 | <.001 | 0.075 | 0.195 |
| Left Wrist Circumference (cm) | 0.543 | <.001 | 0.378 | <.001 | 0.075 | 0.195 |
| Arm Span (cm) | 0.898 | <.001 | 0.614 | <.001 | 0.108 | 0.063 |

{Pearson correlation coefficients (r) were used for comparison based on height, weight and BMI}

## DISCUSSION

This study clearly demonstrated gender dimorphism in upper limb anthropometry. Females had significantly lower length of upper arm, length of forearm, length of total upper limb, hand length, breadth of hand, MUAC, forearm circumference and wrist circumference than males. This pattern of outcomes is like recent Indian research demonstrating gender related differences across multiple hand and upper limb dimensions. In year 2024, cross-sectional study was conducted among 600 Indian adults and the differences was significant gender dimorphism in bilateral hand measurements and reported hand breadth as one of the better discriminating variables for gender estimation.[17] A study of 335 Indian healthcare professionals found differences significant between females and males in hand length, breadth, span and wrist circumference with implications for ergonomic design of hand instruments.[18] Age groups of 21 to 25, 26 to 30 and 31 to 35 years were not showed differences significant and this finding is probably because of the study population as it is restricted to young adults and in them longitudinal skeletal growth is largely complete. There was absence of significant right-left differences in the selected upper limb measurements and due to small mean differences, it is suggesting overall bilateral symmetry in this population. A study of 967 adult male Gujjars from North India showing contrast to this study and there was significant bilateral asymmetry observed in several limb dimensions and the upper extremity measurements had greater asymmetry than lower extremity measurements.[19] Height showed the strongest associations with the dimensions of upper limb in this study. The measurements of upper limb and weight showed moderate positive correlations, especially with total upper limb length, length of forearm and length of upper arm and this indicates that individuals with greater overall body mass may have larger dimensions of upper limb. The total length of upper limb and height showed strong correlation (r = 0.877, p <0.001) whereas the arm span showed even more stronger correlation (r = 0.898, p <0.001) and this findings are more likely to a North Indian community based study of 600 adults where the arm span demonstrated a correlation of 0.90 with stature.[20] With most of the upper limb measurements BMI showed weak association; only the hand length and forearm length demonstrated statistically significant correlations and these findings can be due to BMI is derived measure of body mass relative to height. The relation between MUAC and BMI is yet potentially different. On the basis of Fourth National Family Health Survey data MUAC showed moderate correlation with BMI among both females (r = 0.68) and males (r = 0.56).[21]

Overall, this present study demonstrates that the sex and height are greater informative correlates of upper limb dimensions than the age group or BMI within this adult population. The outcomes of this study showed the value of recording both sides while establishing anthropometric reference data, although no significant asymmetry was observed in this present sample.

**Strength:** The sample for study contains equal numbers of males and females while taken three groups of age are equally represented along with equal sex distribution within each age group. Both sides of the upper limb were assessed, and this allowed the evaluation of bilateral asymmetry. This study includes linear and circumferential measurements. The inclusion of weight, height and BMI help in evaluation of the relationship between regional upper limb dimensions and general anthropometric characteristics.

**Limitation:** The age groups taken was restricted to 21-35 years and so the findings cannot be generalized to children, adolescents or older adults and the samples were distributed according to gender and age group by design and so it may not represent the actual demographic distribution of the large community. Very few participants only 23 were of left-hand dominance and so it is limiting conclusions regarding the effect of hand dominance on bilateral asymmetry. This study did not analyse independent validated regression equations for complete stature estimation of subjects.

## CONCLUSION

This community based cross-sectional study of 300 adults aged 21-35 years showed clear sex related differences and males having the greater measurements than females across all assessed linear and circumferential parameters in selected upper limb dimensions. Three age groups had no significant differences. Right-left differences also showed no significance with measured upper limb parameters, indicating bilateral similarity in this study population. There was moderate association between weight and several upper limb measurements. Height showed the strongest association with linear upper limb dimensions especially the total upper limb length and arm span. BMI showed weak associations with most of the parameters.

The findings of this study provide descriptive anthropometric data for the upper limb in this adult population and demonstrate that sex and height are important correlates of upper limb dimensions, whereas the age group and BMI had limited associations within the studied population.

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