***Original Research Article***

**STATURE ESTIMATION FROM UPPER LIMB MEASUREMENTS IN HEALTHY AND OBESE CHILDREN.**

**ABSTRACT:**

**Background:** The estimation of stature is an essential aspect of anthropometric studies, particularly in children, as it aids in monitoring growth and nutritional status. It is important to understand the relationship between upper limb dimensions and stature, especially for healthy and obese children, given the rising prevalence of childhood obesity.

**Aim:** This study aimed to investigate the relationship between upper limb dimensions—arm length, forearm length, and hand length—and stature among healthy and obese children aged 5 to 12 years.

**Methodology:** This cross-sectional study was conducted in Edo State, Ekpoma community involving 300 children selected through multistage sampling. Anthropometric measurements, including height, weight, arm length, forearm length, and hand length, were taken following standard protocols. Body Mass Index was calculated to categorize children as healthy or obese based on World Health Organization growth standards. Data were analyzed using descriptive statistics, t-tests, Pearson correlation, and multiple linear regression models to predict stature using upper limb dimensions.

**Results:** The mean age of participants was 8.66 years (SD = 2.28), with an average height of 128.39 cm (SD = 13.57). Significant positive correlations were observed between height and upper limb dimensions, with arm length (r = 0.865, p < 0.001), forearm length (r = 0.811, p < 0.001), and hand length (r = 0.857, p < 0.001). The regression model showed that upper limb dimensions explained 83% of the variance in stature (R² = 0.83, p < 0.001), with hand length being the strongest predictor (β = 0.349, p < 0.001). However, logistic regression analysis found that upper limb dimensions poorly predicted underweight status.

**Conclusion:** Upper limb dimensions are reliable predictors of stature in children, emphasizing their utility in anthropometric assessments. The strong correlations and high predictive value suggest their potential application in clinical and field settings for estimating height in both healthy and obese children. However, their ability to predict nutritional status, such as underweight, requires further exploration.

**Key words:** Stature, upper limb dimensions, healthy and obese children, Ekpoma community.

1. **INTRODUCTION**

The prevalence of obesity among children and adolescents has escalated into a global public health concern, significantly affecting both developed and developing countries (Choukem *et al*., 2017; Zhang *et al*., 2017; Ha & Kim, 2016). Obesity in childhood is primarily driven by an energy imbalance, where caloric intake consistently exceeds caloric expenditure. This positive energy balance is often exacerbated by a genetic predisposition to weight gain (Kumar & Kelly, 2017). Alongside genetic factors, lifestyle changes—especially the adoption of sedentary behaviors and the consumption of high-energy foods—has contributed to the rapid increase in obesity rates among children, particularly in developing countries (Mistry & Puthussery, 2015; Poskitt, 2014).

The health consequences of childhood obesity extend far beyond weight gain. Some conditions typically associated with adulthood, such as type 2 diabetes mellitus, hypertension, nonalcoholic fatty liver disease, obstructive sleep apnea, and dyslipidemia, are now increasingly prevalent in overweight and obese children and adolescents (Kumar & Kelly, 2017).

Body mass index (BMI)-for-age is widely recommended by international health guidelines as an ideal measure for assessing obesity in children and adolescents (Kumar & Kelly, 2017). While BMI is practical for clinical and public health use, it has limitations in low-resource settings where equipment, training, and standard measurement conditions may not be available. In field studies with large sample sizes, particularly in resource-constrained areas, BMI evaluations can be challenging and may yield unreliable results (Choukem *et al*., 2017). Consequently, alternative anthropometric indicators that are simpler to measure have been explored as potential substitutes for BMI in these contexts.

In recent years, upper limb dimensions have attracted attention as potential predictors of stature, especially in populations where traditional height measurements are difficult to obtain. Research on estimating stature from upper limb dimensions may offer valuable insights into the assessment of growth patterns and nutritional status in children, providing an additional layer of data to help combat the rising trend of childhood obesity.

The aim of this study is to evaluate the utility of upper limb dimensions in estimating stature among normal and obese children in Ekpoma community of Edo State, Nigeria. This study is significant because it will help in establishing reference values specific to children’s upper limb dimensions which could assist healthcare professionals in monitoring growth and implementing timely interventions. The findings may also contribute valuable insights for public health policies, aligning with global efforts to address the increasing prevalence and early onset of obesity-related health complications among children.

1. **MATERIALS AND METHODS**

**2.1: Study Design and Study Area**

This study adopted a cross-sectional design to investigate the relationship between upper limb dimensions and stature in children. Data was collected from a sample of healthy and obese children aged 5 to 12 years, recruited from selected schools and health centers in Ekpoma community of Edo State.

**2.2: Study Population**

A total of 300 participants were involved in this study. The target population comprised of children aged 5 to 12 years, categorized into healthy and obese groups based on BMI percentiles as defined by the World Health Organization (WHO) growth standards. A multistage sampling technique was employed: first, schools and health centers were randomly selected, followed by the selection of eligible participants from each institution based on inclusion criteria.

**2.3: Study Criteria**

***Inclusion Criteria***: Children aged 5 to 12 years. Participants with parental consent and child assent to participate in the study. Healthy and obese children based on BMI.

***Exclusion Criteria***: Children with any chronic illnesses or conditions affecting growth. Children with physical disabilities impacting upper limb measurements.

**2.4: Data Collection**

The following upper limb dimensions were measured for each participant:

1. **Mid-Upper Arm Circumference (MUAC):** Measured using a flexible, non-stretchable measuring tape at the midpoint between the acromion (shoulder) and the olecranon (elbow). MUAC will be recorded to the nearest 0.1 cm.
2. **Arm Length:** The distance from the acromion to the wrist (styloid process) measured with a measuring tape, recorded to the nearest 0.1 cm.
3. **Forearm Length:** The distance from the olecranon to the wrist (styloid process), also measured with a measuring tape, recorded to the nearest 0.1 cm.
4. **Hand Length:** Hand length was measured from the tip of the middle finger to the distal crease of the wrist using a measuring tape, recorded to the nearest 0.1 cm. Participants were instructed to fully extend their fingers for accurate measurement.
5. **Stature (Height):** Height was measured with a stadiometer, recorded to the nearest 0.1 cm, ensuring the participants were barefoot and standing upright with feet together.
6. **Weight:** Weight was measured using a calibrated digital weighing scale, recorded to the nearest 0.1 kg. Participants were measured barefoot and in light clothing to ensure accuracy.
7. Each measurement was taken twice to ensure accuracy, with a third measurement taken if discrepancies arose between the first two readings. The average of the measurements were used in data analysis.

**2.5: BMI Calculation**:

BMI was calculated using the formula: BMI =Weight (kg)/Height (m)²

BMI percentiles categorized participants as healthy or obese.

**2.6: Data Analysis**

Data was analyzed using IBM SPSS version 26.0. Descriptive statistics, including mean, standard deviation, minimum, and maximum values, were calculated to summarize the anthropometric and demographic characteristics of the study population. Independent t-tests were conducted to compare measurements between sexes and BMI categories, with statistical significance set at p < 0.05. Pearson correlation analysis was performed to assess the relationship between weight, height, arm length, forearm length, and hand length. Logistic regression analysis was applied to identify the predictive capacity of arm length, forearm length, and hand length for underweight status. Receiver Operating Characteristic (ROC) curve analysis and the Area Under the Curve (AUC) were used to evaluate the diagnostic utility of upper limb dimensions.

1. **RESULTS**

**3.1: Anthropometric and Demographic Characteristics**

The anthropometric data of the sample are summarized in **Table 1**. The participants' ages ranged from 5 to 12 years, with a mean of 8.66 years (SD = 2.28). Mean weight was 25.25 kg (SD = 7.20), while mean height was 128.39 cm (SD = 13.57). The BMI varied from 7.8 to 23.49, with an average of 15.04 (SD = 2.084). Arm length, forearm length, and hand length showed respective means of 23.27 cm, 20.40 cm, and 15.78 cm, with standard deviations of 2.99, 2.67, and 1.96.

**Table 1: Descriptive Statistics of Anthropometric and Demographic Characteristics**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **N** | **Minimum** | **Maximum** | **Mean** | **Std. Deviation** |
| **Age** | 300 | 5.0 | 12.0 | 8.66 | 2.28 |
| **Weight** | 300 | 12.0 | 55.0 | 25.25 | 7.20 |
| **Height** | 300 | 99.00 | 186.00 | 128.39 | 13.57 |
| **BMI** | 300 | 7.800 | 23.49 | 15.04 | 2.084 |
| **Arm length** | 300 | 17.00 | 32.00 | 23.27 | 2.99 |
| **Forearm length** | 300 | 16.00 | 31.00 | 20.40 | 2.67 |
| **Hand length** | 300 | 12.00 | 25.00 | 15.78 | 1.96 |

**3.2: Comparison of Anthropometric Measurements by Sex**

The comparison of anthropometric measures between male and female participants is presented in **Table 2**. Although there were slight differences in means, none of the observed differences were statistically significant (all p-values > 0.05). For instance, the mean height for males was 127.27 cm (SD = 13.08), compared to females at 129.38 cm (SD = 13.96, p = 0.441). Similarly, BMI for males (mean = 15.17, SD = 2.15) was slightly higher than for females (mean = 14.93, SD = 2.03, p = 0.354).

**Table 2: Comparison of Anthropometric Measurements by Sex**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Sex** | **N** | **Mean** | **Std. Deviation** | **T-test** | **P-value** |
| **Age** | Male | 141 | 8.65 | 2.39 | -0.081 | 0.067 |
| Female | 159 | 8.67 | 2.18 |
| **Weight** | Male | 141 | 25.07 | 7.27 | -0.405 | 0.940 |
| Female | 159 | 25.41 | 7.16 |
| **Height** | Male | 141 | 127.267 | 13.08 | -1.346 | 0.441 |
| Female | 159 | 129.377 | 13.96 |
| **BMI** | Male | 141 | 15.17 | 2.15 | 1.018 | 0.354 |
| Female | 159 | 14.93 | 2.03 |
| **Arm length** | Male | 141 | 23.03 | 2.86 | -1.355 | 0.263 |
| Female | 159 | 23.49 | 3.11 |
| **Forearm length** | Male | 141 | 20.29 | 2.61 | -0.668 | 0.155 |
| Female | 159 | 20.49 | 2.73 |
| **Hand length** | Male | 141 | 15.62 | 2.02 | -1.336 | 0.705 |
| Female | 159 | 15.92 | 1.90 |

**3.3: BMI and Anthropometric Measurements**

The relationship between BMI categories and anthropometric characteristics is detailed in **Table 3**. Notably, significant differences were observed in age and BMI between underweight and normal-weight individuals. Underweight participants had a mean age of 8.45 years (SD = 2.26), while those with normal BMI were significantly older, with a mean age of 10.26 years (SD = 1.76, p = 0.016). Similarly, BMI differed significantly between groups, with underweight participants having a mean BMI of 14.47 (SD = 1.37), compared to 19.51 (SD = 1.01) in the normal-weight group (p = 0.023). Other parameters such as weight and arm length showed higher mean values in the normal BMI group, though these differences were not statistically significant.

**Table 3: Comparison of Anthropometric Measurements by BMI**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **BMI Category** | **N** | **Mean** | **Std. Deviation** | **T-test** | **P-value** |
| **Age** | **Underweight** | 266 | 8.45 | 2.26 | -4.510 | **0.016\*** |
| **Normal weight** | 34 | 10.26 | 1.76 |
| **Weight** | **Underweight** | 266 | 23.80 | 5.89 | -11.789 | 0.664 |
| **Normal weight** | 34 | 36.59 | 6.46 |
| **Height** | **Underweight** | 266 | 127.35 | 13.53 | -3.765 | 0.193 |
| **Normal weight** | 34 | 136.46 | 11.12 |
| **BMI** | **Underweight** | 266 | 14.47 | 1.37 | -20.668 | **0.023\*** |
| **Normal weight** | 34 | 19.51 | 1.01 |
| **Arm length** | **Underweight** | 266 | 22.98 | 2.86 | -4.990 | 0.976 |
| **Normal weight** | 34 | 25.59 | 3.05 |
| **Forearm length** | **Underweight** | 266 | 20.10 | 2.48 | -5.713 | 0.341 |
| **Normal weight** | 34 | 22.74 | 2.99 |
| **Hand length** | **Underweight** | 266 | 15.59 | 1.91 | -4.775 | 0.539 |
| **Normal weight** | 34 | 17.24 | 1.75 |

**Table 4: Analysis of Variance (ANOVA) for Predicting Height Using Hand Length, Arm Length, and Forearm Length**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ANOVAa** | | | | | | |
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 1 | Regression | 45716.190 | 3 | 15238.730 | 483.218 | .000b |
| Residual | 9334.633 | 296 | 31.536 |  |  |
| Total | 55050.823 | 299 |  |  |  |
| a. Dependent Variable: HEIGHT | | | | | | |
| b. Predictors: (Constant), Hand length, Arm length, Forearm length | | | | | | |

**Table 5: Regression Coefficients for Predicting Height Using Arm Length, Forearm Length, and Hand Length**

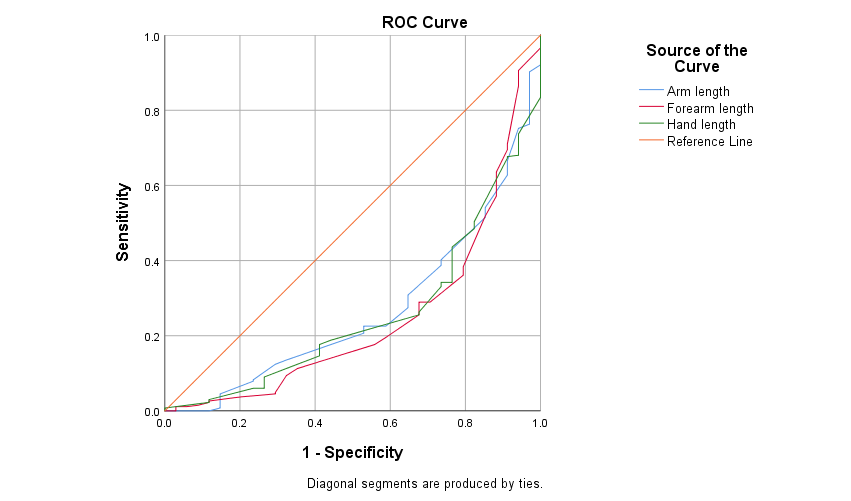
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coefficientsa** | | | | | | |
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| B | Std. Error | Beta |
| 1 | (Constant) | 25.742 | 2.726 |  | 9.442 | .000 |
| Arm length | 1.661 | .223 | .367 | 7.439 | .000 |
| Forearm length | 1.270 | .269 | .250 | 4.725 | .000 |
| Hand length | 2.413 | .324 | .349 | 7.451 | .000 |
| a. Dependent Variable: HEIGHT | | | | | | |

**3.4: Predicting Underweight**

The logistic regression model (see **Table 6**) revealed that none of the variables (arm length, forearm length, and hand length) were significant predictors of underweight status (all p > 0.05). The area under the ROC curve (AUC) values for these predictors ranged from 0.246 to 0.268, indicating poor discriminatory ability.

**Table 6:** Logistic Regression Analysis: Variables in the Equation for Predicting underweight

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables in the Equation** | | | | | | | |
|  | | B | S.E. | Wald | df | Sig. | Exp(B) |
| Step 1a | Arm length | .076 | .115 | .443 | 1 | .506 | 1.079 |
| Forearm length | .258 | .136 | 3.624 | 1 | .057 | 1.294 |
| Hand length | .032 | .176 | .033 | 1 | .856 | 1.033 |
| Constant | -9.944 | 1.779 | 31.227 | 1 | .000 | .000 |
| a. Variable(s) entered on step 1: Arm length, Forearm length, Hand length. | | | | | | | |



**Figure 1: ROC Curve**

1. **DISCUSSION**

This study explored the relationship between upper limb dimensions and stature among healthy and obese children, emphasizing the use of arm length, forearm length, and hand length as predictors of height. The anthropometric characteristics summarized in Table 1 provide insight into the study population. The mean height and weight values aligned with expected growth patterns for children aged 5 to 12 years. Upper limb dimensions, including arm length, forearm length, and hand length, also followed a predictable trend, reflecting the proportional growth of these body parts in relation to overall stature. This supports findings from Yadav & Bhandari (2022), who reported similar proportional relationships in children of comparable age groups. The mean BMI, while within normal limits, demonstrated variability, emphasizing the heterogeneity of the sample.

The comparison of measurements between male and female participants in Table 2 showed minimal differences, with none reaching statistical significance. For instance, the mean height of males was slightly lower than that of females, but this difference was not significant (p = 0.441). Similarly, BMI comparisons revealed no substantial sex-based disparity (p = 0.354). These findings suggest that upper limb dimensions and overall growth patterns are consistent across sexes in early childhood, aligning with the work of Ye *et al* (2019), who also observed negligible sex differences in anthropometric measurements at this stage of development.

The relationship between BMI categories and anthropometric characteristics, detailed in Table 3, highlighted key differences between underweight and normal-weight participants. Notably, children with normal BMI had higher mean values for height and upper limb dimensions, although these differences were not statistically significant. However, BMI showed significant variation, with underweight children exhibiting lower values than their normal-weight counterparts. These results correlate with Nuttall (2015) and Wu *et al* (2024), who found that BMI is a critical indicator of overall growth and nutritional status but may not directly influence limb proportions.

A strong positive correlation between height and upper limb dimensions, presented in Table 4, shows the interdependence of these measurements. For example, height was strongly correlated with arm length and hand length, reflecting their proportional growth. These findings are consistent with those of Edmond *et al* (2020), who demonstrated that upper limb dimensions are reliable indicators of stature in pediatric populations. The high correlation coefficients further validate the use of these measures in practical applications, such as forensic identification and pediatric health assessments.

The regression analysis in Table 5 revealed that arm length, forearm length, and hand length significantly predicted height, with a combined R² value of 0.83. Among these predictors, hand length had the largest contribution, followed closely by arm length and forearm length. These results align with Amitava *et al* (2016), who also identified hand length as a strong predictor of stature. The high predictive value of the model highlights the potential of upper limb dimensions for accurate height estimation, especially in settings where direct height measurements are impractical.

The logistic regression analysis in Table 6 showed that arm length, forearm length, and hand length were not significant predictors of underweight status. The poor discriminatory ability of these variables, as indicated by the AUC values suggests that upper limb dimensions may not be reliable indicators of nutritional status. This contrasts with the findings of Liu *et al* (2022), who reported moderate predictive utility for these measures in assessing underweight status. The discrepancy could be attributed to differences in sample characteristics or methodological approaches.

The findings of this study have several practical applications. The strong correlations and predictive relationships between upper limb dimensions and height suggest that these measures can be used in various settings, including pediatrics, forensics, and nutritional assessments. For example, in clinical settings where direct height measurements are difficult, such as with bedridden patients or children with physical disabilities, upper limb dimensions provide a viable alternative. Additionally, these measures can assist in designing ergonomic tools, clothing, and equipment tailored to children’s body proportions.

The results of this study are consistent with earlier research emphasizing the utility of upper limb dimensions in estimating stature. For instance, Sarma *et al*. (2020) and Yadav & Bhandari (2022) reported similar correlations between arm length and height in Indian children, while Amitava *et al*. (2016) highlighted the robustness of hand length as a predictor. However, the inability of upper limb dimensions to predict underweight status contrasts with Liu *et al*. (2022), suggesting the need for further investigation into the role of these measures in nutritional assessments.

1. **CONCLUSION**

This study revealed the utility of upper limb dimensions in estimating stature among healthy and obese children. The findings, supported by significant correlations and regression analyses, highlight the strong predictive power of arm length, forearm length, and hand length. While these measures are effective for height estimation, their limited utility in predicting underweight status suggests the need for further research. Overall, this study contributes to the growing body of evidence supporting the use of anthropometric measures in pediatric health and nutrition.

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