# Prediction of Height Using Arm Span And Ulna Length Among Malaysian Adolescents 

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#### Abstract

Background: Height measurement is frequently used anthropometric techniques in medical practice to evaluate health status. The measurement of height is encumbered by deformities of joint of spine, or muscle weakness. Numerous anthropometric studies had been conducted using different segments of the body as a surrogate height measurement such as arm span and ulna length. Methods: This study aims to identify the correlation and establish linear regressions for the estimation of height from arm span and ulna length in Malaysia adolescent population. Males ( $n=175$ ) and females ( $n=211$ ), aged 13, 14 and 16 years old, without disability were recruited from Selangor schools. Height, arm span and right and left ulna lengths were measured. Results: Prediction equations for height based on arm span, ulna lengths and age were generated using regression analysis. For males, Estimated height (cm) $=0.707$ (arm span) +1.212 (age) $+28.281 \pm 3.56$; Estimated height $=2.333$ (left ulna length) +2.399 (age) $+67.878 \pm 5.750$; Estimated height $=$ 2.435 (right ulna length) +2.097 (age) $+69.667 \pm 5.757$. For females, Estimated height $=0.658($ arm span $)+$ 0.863 (age) $+40.107 \pm 3.49$; Estimated height $=1.752$ (left ulna length) +1.479 (age) $+90.648 \pm 5.393$; Estimated height $=1.786$ (right ulna length) +1.480 (age) $+89.663 \pm 5.375$. Arm span showed a higher accuracy compared to ulna length based on $R$ square value. However, ulna measurement appears to be surpassed arm span measurement when deformities exist according to other literatures. Conclusion: The overall study is beneficial in predicting height of adolescent with deformities when standing height is difficult to be measured.


Keywords: Anthropometric; height prediction; Malaysian adolescent; arm span; ulna length

## INTRODUCTION

Anthropometry refers to a series of organized measuring techniques that are used to demonstrate quantitatively the dimensions of human body and skeleton. As it predicts the health, performance and survival of an individual, it is a beneficial tool for assisting public health policy and clinical decisions ${ }^{1}$.

Growth assessment in children is a pivotal aspect of health care maintenance and is primarily used by physicians to screen the endocrine functionality ${ }^{2}$, medical integrity and health, and also as an indicator of nutritional status ${ }^{3}$. Children's growth can be assessed effortlessly by measuring the standing height. Moreover, the relationship between height and bodyweight indicate the level of nutrition ${ }^{4}$. Height is not only essential in calculating BMI and body surface area, but also crucial in estimating blood pressure, renal function as well as pulmonary function ${ }^{5}$. Furthermore, standing height is imperative to estimate the weight for calculating the drug dosage of strict-weightbased drugs in critically ill patients during emergencies ${ }^{6}$.

Numerous anthropometric studies had been conducted using different segments of the body such as knee height, arm span, demi span, leg length and ulna length as a surrogate height measurement and this is also clinically used for those patients who cannot afford to stand up on their feet to obtain the standing height, especially in those with neurological disorders, muscular diseases, myelomeningocele, joint contractures, spinal or chest deformities, severely injured or other medical conditions
that affect the growth ${ }^{7}$. Moreover, as they have the higher tendency to get pulmonary complications such as infections and collapsing of lungs, surrogate measurements play a vital role in predicting their height and at the same time assessing health status such as pulmonary function ${ }^{8-10}$. Arm span and ulna length are especially useful and effective in predicting height according to various studies.

Several researchers have suggested the statistical regression of the standing height with the subcutaneous ulna length and arm span in various countries such as Portugal and England, Vietnam, Australia, India, London and USA ${ }^{7,3,11-15}$. In Malaysia, a study has been conducted in predicting stature using arm span in elderly patients ${ }^{16}$. Till date, the data is quite lacking for Malaysian adolescent aged 13 to 17, as per the literature. This study aims to identify the correlation and formulate the equations for the valuation of height from the arm span and ulna length. Moreover, the study is motivated to find out the relationship between some demographic data such as age, ethnicity and gender with the height measurement.

## MATERIALS AND METHODS

Ethics: Initially, authorization was obtained from the University research board, Ministry of Education (MOE), Selangor Education Department, as well as the principals from the targeted schools and parents or guardian of each subject.

A cross-sectional study was conducted on Malaysian adolescents who are studying in Selangor area in 2019

December. Convenience sampling method was used with the sample size ( $n=386$ ) of consenting Malay, Chinese and Indian students of both genders aged 13, 14 and 16 years were enrolled. Questionnaire and consent forms were distributed before collecting the data from participants. Individuals with any deformities in the upper limbs or vertebral column or both, disease known to cause growth disturbance, muscle weakness, use of medications considering disruption in the growth and those who were not willing to volunteer were excluded in this study. The data collection was taken in one day per school, and measurement of each subject took less than 5 minutes.

The height of the subject was measured with the subject standing erect and barefooted. The weight of the subject was evenly distributed on both feet. They were asked to look forward with the head maintained in the Frankfort Horizontal Plane position while the height measuring rod lowered to the crown of the head with adequate pressure to compress the hair.
With the subject stood with their heels together and stretched their arms and both palms facing anteriorly ${ }^{17}$, arm span was measured using a steel measuring tape from the tip of the middle finger on one hand across the chest to the tip of the middle finger on another hand.

In a sitting position, the forearm of each subject was placed comfortably on a table, and the ulna length was measured using the same steel measuring tape from the tip of olecranon process to the tip of the styloid process for both left and right hands ${ }^{3}$.

Te acquired values were statistically analyzed using IBM $®$ SPSS® Statistics version 23 software. The Correlation coefficient determined the prediction of a significant relationship amongst the variables. It was established by simple regression, with the Regression constant (a), Regression coefficient (b), where the model of the regression equation was $y=a+b x$. A $95 \%$ confidence interval was accepted, and the standard error of the regression (STE) was calculated.

## RESULTS

The completed questionnaire and the consent forms were collected. Data was analyzed by comparing the genders.

The mean of the heights was generalized as 162.46 cm for male, and 154.75 cm for female, with a standard deviation of 8.78 and 6.81 respectively.

Among the variables tested, there are strong correlations between arm span, left and right ulna lengths of different gender, age and ethnicity with height as indicated in the Pearson correlation coefficient (r) (Table I). The precision of prediction of height from arm span, left and right ulna length and age is proportional, and each variable shows a significant correlation with height measurement ( $p<0.001$ ). Coefficient of correlation (R), Coefficients of determination (R square) and Adjusted R square for each variable were done.

Ethnicity did not show significant value in predicting the equations. Left and right ulna lengths showed moderate strength of $R$ square with the range of 0.306 to 0.51 . Ulna lengths showed a higher $R$ square value when age is included. Arm span showed the highest correlation of coefficient (R) (male $=0.903$, female $=0.846$ ). The represented prediction equations have $R$ square of 0.815 and 0.716 for gender, in comparison with the values of 0.838 and 0.740 , when age is included. The statistical outcome that showed the inter-relationship of arm span and height in both male and female are demonstrated in Table II and Table III.
Thus, the regression equations are as below:

## Males, $\mathrm{n}=175$

- Estimated height $=0.707$ (arm span)+1.212(age) $+28.281 \pm 3.56$
- Estimated height $=2.333$ (left ulna length) +2.399 (age) $+67.878 \pm 5.750$
- Estimated height= 2.435(right ulna length) +2.097 (age) $+69.667 \pm 5.757$ Females, $\mathrm{n}=211$ :
- Estimated height $=0.658($ arm span $)+0.863($ age $)+$ $40.107 \pm 3.49$
- Estimated height $=1.752$ (left ulna length) +1.479 (age) $+90.648 \pm 5.393$
- Estimated height $=1.786$ (right ulna length) +1.480 (age) $+89.663 \pm 5.375$

Table I: Correlations between arm span, left and right ulna lengths of different gender, age and ethnicity with height

|  |  | Gender | Standing_height | Arm_Span | Ulna_left | Ulna_right | Age | Ethnicity |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Gender | Pearson Correlation | 1 | -. $444{ }^{\text {" }}$ | -.466* | -.283* | -.260" | -. 078 | -. 017 |
|  | Sig. (2-tailed) |  | . 000 | . 000 | . 000 | . 000 | . 124 | . 733 |
|  | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| Standing_height | Pearson Correlation | -. $444{ }^{\prime \prime}$ | 1 | .903** | .665** | 669** | . 486 " | .177* |
|  | Sig. (2-tailed) | . 000 |  | . 000 | . 000 | . 000 | . 000 | . 000 |
|  | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| Arm_Span | Pearson Correlation | -. $466{ }^{\text {" }}$ | . $903{ }^{*}$ | 1 | . $688{ }^{\text {* }}$ | .676" | . $404 *$ | .121* |
|  | Sig. (2-tailed) | . 000 | . 000 |  | . 000 | . 000 | . 000 | . 017 |
|  | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| Ulna_left | Pearson Correlation | -. $283{ }^{\text {" }}$ | . $665{ }^{*}$ | . $688{ }^{*}$ | 1 | .887" | . 381 " | . $101^{*}$ |
|  | Sig. (2-tailed) | . 000 | . 000 | . 000 |  | . 000 | . 000 | . 047 |
|  | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| Ulna_right | Pearson Correlation | -. $260{ }^{\prime \prime}$ | .669** | .676** | .887* | 1 | .408** | .170" |
|  | Sig. (2-tailed) | . 000 | . 000 | . 000 | . 000 |  | . 000 | . 001 |
|  | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| Age | Pearson Correlation | -. 078 | . $486{ }^{\text {" }}$ | .404** | . 381 " | .408** | 1 | . $267{ }^{\text {² }}$ |
|  | Sig. (2-tailed) | . 124 | . 000 | . 000 | . 000 | . 000 |  | . 000 |


| Ethnicity | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |
| :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Pearson Correlation | -.017 | $.177^{* \prime}$ | $.121^{\circ}$ | $.101^{*}$ | $.170^{* \prime}$ | $.267^{* \prime \prime}$ | 1 |
|  | Sig. (2-tailed) | .733 | .000 | .017 | .047 | .001 | .000 |  |
|  | N | 386 | 386 | 386 | 386 | 386 | 386 | 386 |

${ }^{* *}$ Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed).
Table II: Relationship of arm span and height of male Malaysian adolescents.

| Male |  | Independent variable |
| :--- | :---: | :---: |
|  | Arm span_Age | Dependent variable |
| Regression constant (a) | 28.281 |  |
| Regression coefficient (b) for arm span | $0.707(p<0.001)$ |  |
| Regression coefficient (b) for age | $1.212(p<0.001)$ |  |
| Standard Error of estimate (STExy) | 3.56 |  |

Table II shows different statistical outcomes demonstrating a significant correlation between arm span and height of male Malaysian adolescent ( $\mathrm{N}=175$ ).

Table III: Relationship of arm span and height of female Malaysian adolescents.

| Female | Independent variable | Dependent variable |
| :--- | :---: | :---: |
|  | Arm span_Age | Height |
| Regression constant (a) | 40.107 |  |
| Regression coefficient (b) for arm span | $0.658(\mathrm{p}<0.001)$ |  |
| Regression coefficient (b) for age | $0.863(\mathrm{p}<0.001)$ |  |
| Standard Error of estimate (STExy) | 3.49 |  |

Table III shows different statistical outcomes demonstrating a significant correlation between arm span and height of female Malaysian adolescent ( $\mathrm{N}=211$ ).

## DISCUSSION

Each surrogate measurement is reproducible and able to provide accurate substitute to standing height for assessment of health status such as pulmonary function which is commonly practised in clinical settings. Previous studies have documented the relationship between height and various body segments in their study population ${ }^{3,7,11,12}$. Remarkable emphasis has been paid to the arm span and ulna length because both have high accessibility ${ }^{3,8}$. Some researchers have analyzed the reliability of the equations of Gauld et al. to predict height based on body segments, and to estimate BMI in a sample of different nationality subjects, such as Argentine children ${ }^{7}$.

In this study, the Pearson correlation coefficient (r) of the height and arm span was 0.903 , left ulna length 0.665 and right ulna length 0.669 . These values implied that there was a strong association, especially arm span, that had a significant contribution towards height estimation, which is compliance with other studies ${ }^{3,7,11-13,15,18}$. Arm span showed highest $R$ square value (male $=0.815$, female $=0.716$ ) compared to left ulna length (male $=0.483$, female $=0.306$ ), right ulna length (male $=0.51$, female $=0.31$ ) and age (male=0.354, female $=0.178$ ) variables. However, when arm span and age were both calculated as a predicted value, it showed a higher $R$ square value (male $=0.838$, female $=0.74$ ) compared to taking arm span alone into the equation. Hence, age was added into the predicted equation for higher accuracy. In comparison to arm span, ulna length is a suitable parameter to measure in patients with joint weakness or spinal disorders, as the bony landmarks were recognized easily, and the measurement was unhindered ${ }^{8,12}$. But in terms of accuracy, arm span could provide a better prediction of height as seen in the R square value and the graph represented in the result section.

It is undeniable that certain level of inaccuracies was produced throughout the study due to some limitations.

Even though steel measuring tape is more feasible to measure arm span, measurement should be taken using a Harpenden anthropometer as proposed in one of the studies $^{3}$ for more precise measurement. Besides, adolescent aged 15 and 17 years old could not be included in the study, and only students aged 13, 14 and 16 were participated in the study. This age group limitation may affect the precision of the equation.

## CONCLUSION

Measurement of height is a significant component in assessing health status, such as identifying the developmental deviations or impact of a disease or intervention. Measuring the standing height is not possible always, for instance, in individuals with neuromuscular weakness, immobility and other joint or spinal deformities. The present study showed a positive and statistically significant correlation of arm span and ulna length with the height for the adolescent population in Malaysia. It is found that regression formula derived from arm span produces a better accuracy result than ulna length based on the R square value. However, based on studies, ulna length would provide a precise predictor in children with disability, as ulna length usually would not be affected in a patient with deformities. The overall study is useful in estimating height for Malaysian adolescent with disabilities when the standing height is difficult to be obtained.
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