Determination of the Actual Height Predictors in Iranian Healthy Children

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Abstract- Height measurement is an important part of nutritional assessment especially in children. However, in such cases as hospitalized or certain kinds of malformations or disabilities, height cannot be measured accurately. We aimed to determine appropriate height predictors in Iranian healthy children for further use in disabled and/or hospitalized children. A total of 730 apparently healthy children aged 7-11 years old from both sexes from Tehran, Meshed and Rasht were enrolled in a cross sectional study. Height, demispan (DS), halfspan (HS), arm length (AL) and tibia length (TL) were all measured using a measuring tape. Linear regression models were established between height, DS, HS, AL and TL. For boys AL (R^2=0.783) and TL (R^2=0.837) and for girls AL (R^2=0.720), TL (R^2=0.765), HS (R^2=0.771) and age (R^2=0.775), respectively, entered the linear regression model. When height predictors were evaluated individually for each city, only in Tehran DS also entered the regression model. Concordance of different percentiles of height estimates based on AL with those of actual height proposed this measure as a reliable height proxy for this age group in clinical as well as field practice.

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Introduction

Disabled children are at great risk of malnutrition for many reasons (1, 2) so they need to receive special dietary cares (3). Indeed, proper nutrition not only affects survival of disabled as well as non-disabled children, but may influence their quality of life as well (4).

To manage nutritional problems, assessment of nutritional status is the first step. Anthropometric assessment is usually very informative and easy to use. However, it is not always a simple task in a disabled child. In paraplegia, for instance, mid-upper arm circumference (MUAC) and triceps skin-fold thickness (TSF) could be misleading as arm muscles may be strengthened and subcutaneous fat of arms may be lessened irrelative of the whole nutritional status due to using wheelchair or walking aids (5). Height, which shows the linear growth of the child, cannot be measured correctly in vertebral or lower limbs malformations (6).

To overcome this latter problem, such other anthropometric measures as arm length (7), tibia length (8), knee height (9), armspan (10), demispan (11) and halfspan (2) have been used to estimate height in those subjects whose height cannot be measured accurately for any reason such as hospitalization or disability. To do this, it is necessary to calculate and validate the regression equations in a corresponding healthy population (12).

However, it has been shown that relationship between anthropometric measures may be different between different ethnic and even between different stature groups (8). This is the first report of evaluation of arm length, tibia length, halfspan and demispan as predictors of height in Iranian non-disabled primary school children for further use in disabled and/or hospitalized children.

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Patients and Methods

In the first step, a short-term workshop was held for Meshed and Rasht observers, who were less experienced in this field, at the Deputy of Research, National Nutrition and Food Technology Research Institute, by a training team who had a vast experience in anthropometry in a national survey (National Comprehensive Study on Household Food Consumption Pattern and Nutritional Status, IR Iran, 2001-2003. Tehran, Shahid Beheshti Medical University, National Nutrition and Food Technology Research Institute, Department of Nutrition Research, 2005; National Report). During one day training course, a brief on the research project including nutritional assessment and the techniques of measuring height, arm length (AL), tibia length (TL), halfspan (HS) and demispan (DS) was taught to the participants then after they practiced the techniques under the instructions of the supervisors.

In the next step, 730 apparently healthy children aged 7-11 years old from both sexes from Tehran (n_1=543), Meshed (n_2=87) and Rasht (n_3=100) were enrolled in a cross sectional study. These subjects were actually the control group of another research project on nutritional status of physically disabled children. Height, DS, HS, AL and TL were all measured using a measuring tape to the nearest of 0.1cm. Weight was measured by a digital scale (Seca 840, Germany) to the nearest of 0.1kg. Body mass index (BMI) was calculated using the formula weight (kg)/height^2(m).

Statistical analyses. Data was expressed as mean ± standard deviation (SD). Normality of data distribution was evaluated using Kolmogrov-Smirnov. To establish a regression model between height and the other measures, i.e. DS, HS, AL and TL, Pearson correlation coefficients were determined followed by stepwise linear regression analysis. Comparison of means between the groups was carried out by Student *t* test and analysis of variance (when the distributions were normal) or Mann-Whitney U-Wilcoxon and Kruscal Wallis (when the distributions were not normal). All analyses were done using Windows/Statistical Package for Social Sciences (SPSS) version 14.

Results

Age, height, weight and BMI differed significantly in the three cities. Height significantly correlated with AL, DS, HS and TL (p<0.001). However, for boys AL (R^2=0.783) and TL (R^2=0.837) and for girls AL (R^2=0.720), TL (R^2=0.765), HS (R^2=0.771) and age (R^2=0.775), respectively, entered the linear regression model. When height predictors were evaluated individually for each city, only in Tehran DS also entered the regression model. The following equations obtained to predict actual height:

Estimation of boys' height:

1) Ht = 35.114 + (AL × 2.69), R^2 = 0.783
2) Ht = 41.97 + (AL × 1.851) + (TL × 0.588), R^2 = 0.837

Estimation of girls' height:

3) Ht = 45.011 + (AL × 2.492), R^2 = 0.720

However, when regression analysis was performed for each city and gender, for boys in Tehran TL (R^2 = 0.913), HS (R^2 = 0.938) and AL (R^2 = 0.939) and in Meshed only TL (R^2 = 0.961) and in Rasht only AL (R^2 = 0.963) entered the model. For girls in Tehran HS (R^2 = 0.861), TL (R^2 = 0.900), AL (R^2 = 0.904) and age (R^2 = 0.906), in Meshed only AL (R^2 = 0.947) and in Rasht also only AL (R^2 = 0.886) entered the model. The regression equations thus obtained are:

Tehran, boys:

4) Ht = 38.342 + (TL × 2.231), R^2 = 0.913
5) Ht = 24.277 + (TL × 1.481)+(HS× 0.666), R^2 = 0.938
6) Ht = 23.830+ (TL × 1.366) + (HS × 0.607) + (AL × 0.258), R^2 = 0.939

When regression analyses were done with each individual predictor just for Tehran children, HS and DS also entered the model. The equations were as follows:

In Tehran:

Boys:

7) Ht = 39.260 + (TL × 2.215), R^2 = 0.676
8) Ht = 26.988 + (HS × 1.565), R^2 = 0.632
9) Ht = 26.834 + (DS × 1.726), R^2 = 0.624
10) Ht = 47.446 + (AL × 2.390), R^2 = 0.577

Girls:

11) Ht = 47.388 + (TL × 2.066), R^2 = 0.708
12) Ht = 32.766 + (HS × 1.493), R^2 = 0.741
13) Ht = 35.538 + (DS × 1.604), R^2 = 0.730
14) Ht = 54.412 + (AL × 2.257), R^2 = 0.658

Arm length (AL) entered the model in all three cities so it was possible to calculate equations based on data obtained from three cities:

Boys:

15) Ht = 33.323 + (AL × 2.2.740), R^2 = 0.739

Girls:

16) Ht = 41.652 – (AL × 2.579), R^2 = 0.752

As there was no significant difference in height the other anthropometric measures between two sexes (Table 1), general equations, irrespective of gender, were also calculated to predict actual height as follows:

17) Ht = 43.657 + (TL× 2.134), R^2 = 0.751
18) Ht = 30.179 + (HS × 1.524), R^2 = 0.748
19) Ht = 31.732 + (DS × 1.656), R^2 = 0.740
20) Ht = 38.152 + (AL × 2.646), R^2=0.733

Table 1. Age and some selected anthropometric measures of healthy children in Tehran, Mashhad and Rasht

City	Boys				Girls			
Measure	Tehran (n=226)	Mashhad (n=49)	Rasht (n=42)	Total	Tehran (n=317)	Mashhad (n=38)	Rasht (n=58)	Total
Age (yrs)	10.2±0.6^{a}	8.9±1.8^{b}	9.1±1.2^{b}	9.8±1.1	10.2±0.7^{a}	8.9±1.5^{b}	7.5±1.8^{c}	9.7±1.4
Ht (cm)	140.0±7.1^{a}	128.4±11^{b}	132.8±13.0^{c}	*137.4±9.8*	141.5±7^{a}	124.2±12.6^{b}	132.9±7.8^{c}	*139.6±8.5*
Wt (kg)	35.9±8.8^{a}	27.4±7.9^{b}	26.2±6.0^{b}	33.3±9.3	37±8.7^{a}	26.9±5.9^{b}	26.9±6.7^{b}	34.6±9.3
BMI (kg/m^2)	18.2±4.0^{a}	17.4±5.7^{a}	15±2.8^{b}	17.7±4.3	18.3±3.3^{a}	16.9±4.9^{ab}	15.0±2.6^{b}	17.8±3.5
TL (cm)	45.6±2.9^{a}	34.4±3.6^{b}	35.1±5.8^{b}	42.5±6.0	45.5±2.8^{a}	34.4±3.4^{b}	33.8±3.1^{b}	43.1±5.6
HS (cm)	72.4±4^{a}	66.0±5.4^{b}	64.6±5.3^{b}	70.4±5.4	72.8±4.0^{a}	65.4±6.3^{b}	63.6±3.2^{b}	70.8±5.5
DS (cm)	65.7±3.6^{a}	60.1±5.3^{b}	58.8±5.4^{b}	63.9±5.0	66.0±3.7^{a}	59.2±5.8^{b}	57.4±3.0^{b}	64.2±5.1
AL (cm)	38.8±2.5^{a}	34.4±8^{b}	35.8±4.2^{b}	37.8±4.4	38.6±2.5^{a}	34.8±8.4^{b}	35.1±2.3^{b}	37.9±2.9

Numbers in a row not sharing a common superscript are significantly different (P<0.02). Total numbers in italic in a row are significantly different (P=0.002). Abbreviations: AL: arm length; DS: demispan; HS: halfspan; Ht: height, TL: tibia length.

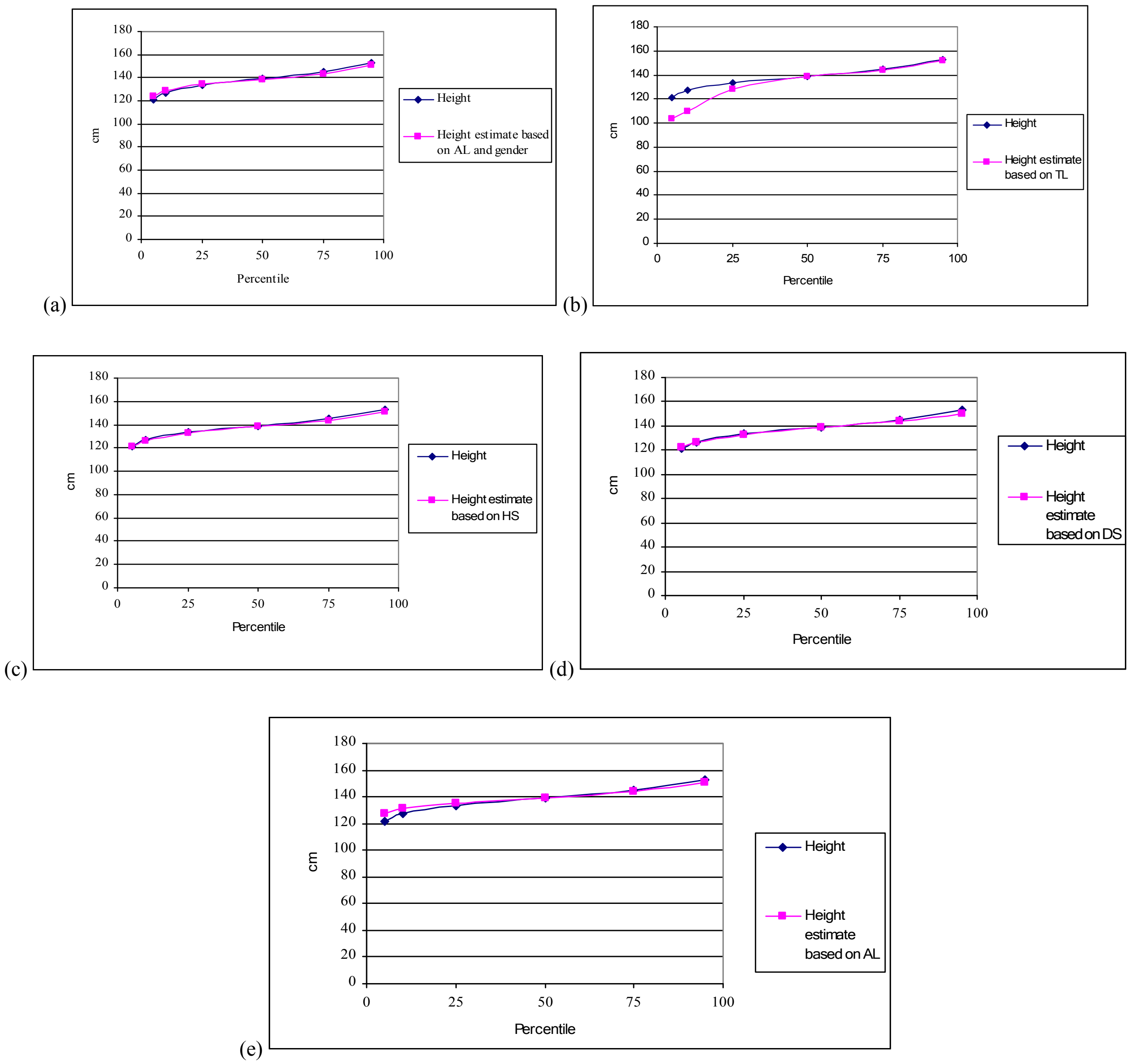

Figure 1. Comparison of the percentiles of actual height and height estimates based on (a) arm length (AL) and gender; (b) tibia length (TL); (c) halfspan (HS); (d) demispan (DS); and (e) arm length (AL).

Table 2. Comparison of the actual heights with those estimated using height predictors in different regression equations in healthy children of Tehran, Mashhad and Rasht

City	Number of Subjects	Ht (cm)	Estimation of Height Based on Equation No:					*P* value
			15 & 16	17	18	19	20	
Tehran	543	140.9±7.1	140.5±6.6	141.4±7	141±6.1	141±6.1	141±5.7	0.349
Meshed	87	127.4±11.4	137.9±8.1	105.6±27.1	130.5±8.9	130.7±9.1	135.0±8.6	<0.001
Rasht	100	132.9±10.2	132±8.6	114.2±10.9	127.8±6.4	127.8±7	133.5±7.4	<0.001
P value		<0.001	<0.001	0.019	<0.001	<0.001	<0.001	

Equations 15 and 16 are based on arm length and gender. Equations 17, 18, 19 and 20 are based on tibia length, halfspan, demispan and arm length irrespective of gender. (see the text for more details.)

Comparison of the measures, rows: In Meshed only height estimate based on tibia length was significantly different with the other measures. In Rasht, only height estimates based on arm length (equations 15, 16 and 20) did not show significant difference with the mean actual height; columns: mean height estimates based on arm length and gender (equations 15 and 16) were significantly different between Tehran and Rasht ($P = 0.015$). Mean height estimate based on arm length (equation 20) in Tehran was significantly different compared to those of Mashhad and Rasht but there was no statistically difference between these two cities.

Based on the above equations, children heights were estimated and compared with their actual heights (Table 2). Different percentiles of actual heights and height estimates showed a very good agreement (Figure 1). Strong correlations were found between actual heights and height estimates based on AL alone ($P<0.001$), AL and gender, TL, HS and DS ($P<0.001$) (Figure 2).

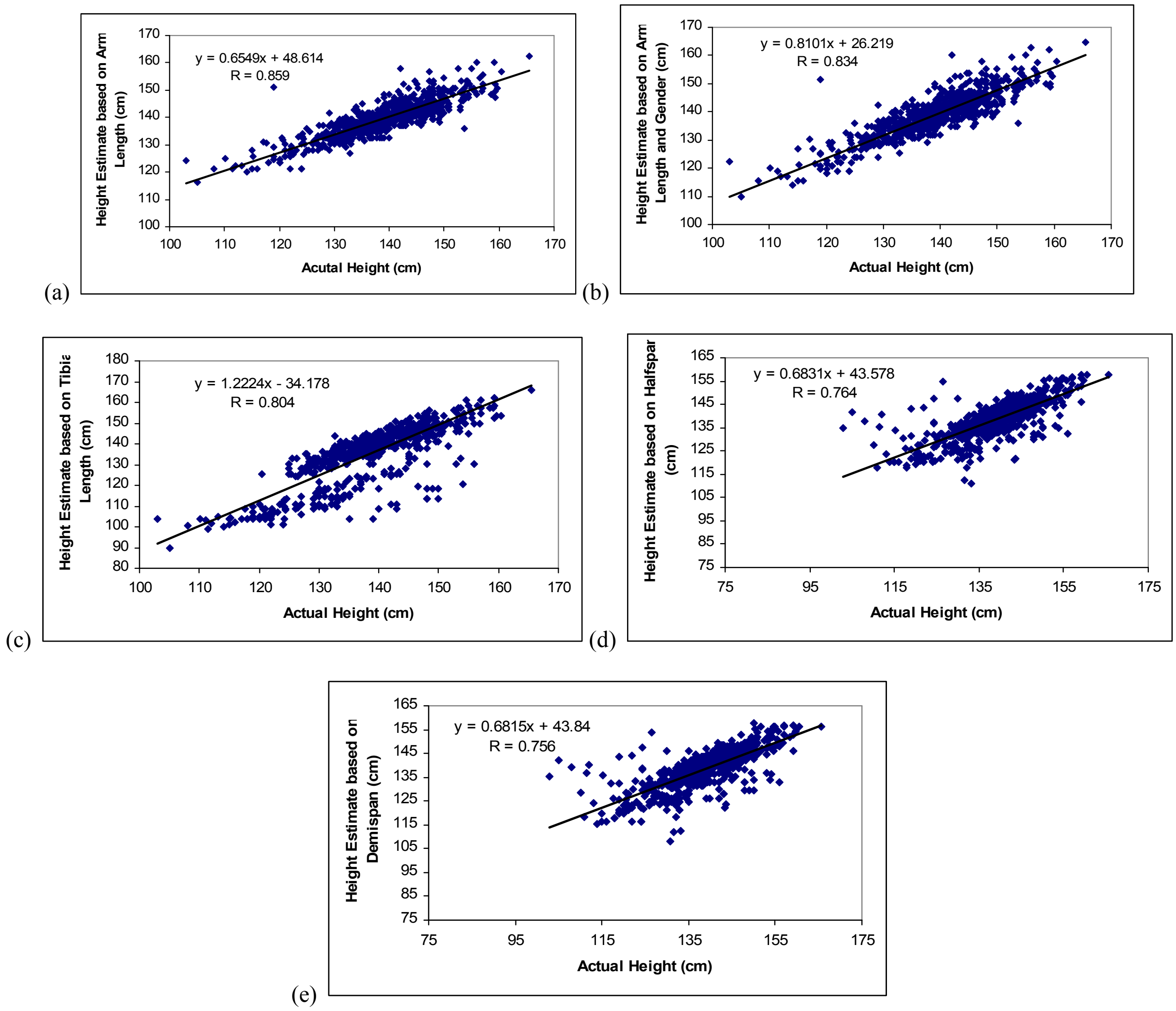

Figure 2. Correlations between actual heights and height estimates based on (a) arm length; (b) arm length and gender; (c) tibia length; (d) halfspan; and (e) demispan.

Discussion

Height is an important part of nutritional assessment both for growth monitoring and in clinical setting. However, in some situations height measurement cannot be done accurately. In some hospitalized patients and certain physically disabled subjects, for instance, height measurement is impractical. In these situations, some other anthropometric measures, such as AL, AS, DS, HS and TL, may be used as proxies of height. However, it has been shown that the relationship between these proxies and height may vary with ethnicity and gender (13).

Armspan, the distance between middle finger tip of one hand to the other while the arms are wide open, has been used as a predictor of height in Chinese (10, 14) as well as Ethiopian (13) adult population. Both AS and HS have also been used to evaluate nutritional status of adults (15) as well as children (16). However, measuring armspan in some cases such as physically disabled children with spastic problems of arms may not be possible.

Our data showed that AL could be a good predictor of height with the advantage that it could be done with minimum training and skill of the observer and, moreover, it can be used as a height proxy in most, if not all, disabled children. Arm length has been shown to be inversely associated with the severity of dementia and cognitive function in elder people (17). Further research is needed to evaluate if AL is affected by cognitive function independent of height in a disabled child.

Tibia length, measured accurately with a standard tape, has been reported as a reliable proxy of height (18). In our study, TL though entered the model, was a very weaker predictor of height than AL. The association between TL and height was even weaker in girls compared to the boys. Significant difference between actual heights and height estimates based on TL in Meshed and Rasht was probably due to measuring errors necessitating more training of the observers.

Knee height was introduced as a reliable predictor of height in subjects aged 6-18 years old (9). In adult patients with cerebral palsy and physical disability, recumbent height may also be estimated using knee height measured by a caliper (19). However, it was shown that TL had the greatest error when used in field surveys (1). Moreover, there is one report of stature type-specificity of TL for predicting actual height (8). In our one-day workshop, we found even higher inter- and intra-observer variations for KH than for TL. Arm length, on the other hand, showed minimum variations and in most, if not all, cases it was very easy to measure. In conclusion, concordance of different percentiles of height estimates based on AL with those of actual height proposed this measure as a reliable height proxy for this age group in clinical as well as field practice.

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