The relationships between height and arm span, mid-upper arm and waist circumferences and sum of four skinfolds in Ellisras rural children aged 8–18 years

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Abstract

Objective: Height is required for the assessment of growth and nutritional status, as well as for predictions and standardization of physiological parameters. To determine whether arm span, mid-upper arm and waist circumferences and sum of four skinfolds can be used to predict height, the relationships between these anthropometric variables were assessed among Ellisras rural children aged 8–18 years.

Design: The following parameters were measured according to the International Society for the Advancement of Kinathropometry: height, arm span, mid-upper arm circumference, waist circumference and four skinfolds (suprailiac, sub-scapular, triceps and biceps). Associations between the variables were assessed using Pearson correlation coefficients and linear regression models.

Setting: Ellisras Longitudinal Study (ELS), Limpopo Province, South Africa.

Subjects: Boys (n 911) and girls (n 858) aged 8–18 years.

Results: Mean height was higher than arm span, with differences ranging from 4 cm to 11·5 cm between boys and girls. The correlation between height and arm span was high (ranging from 0·74 to 0·91) with $P < 0·001$. The correlation between height and mid-upper arm circumference, waist circumference and sum of four skinfolds was low (ranging from 0·15 to 0·47) with $P < 0·00$ among girls in the 15–18 years age group.

Conclusions: Arm span was found to be a good predictor of height. The sum of four skinfolds was significantly associated with height in the older age groups for girls, while waist circumference showed a negative significant association in the same groups.

Height and body mass are important parameters to measure in the assessment of adiposity in children and adults[1]. Given the well-documented limitations of BMI in the assessment of obesity, future basal metabolic risk and standardization of physiological parameters like muscle strength and glomerular filtration rate during human growth[2,3], waist circumference, mid-upper arm circumference (MUAC) and skinfold thickness are leading direct methods used to assess fat distribution[4,5]. There are established relationships between height and different body dimensions in adult human beings. The relationship between height and arm span is reported by some authors[6–11] while other studies have reported the estimation of height from arm span[12–15]. Furthermore, height has been estimated from the dimensions of upper and lower extremities[9,16,17]. However, in the fracture of vertebrae or paralysis situation, measuring height is difficult[18]. In such a situation, measurements such as arm span, waist circumference, knee height, arm length, sitting height, MUAC and skinfold thickness could be used[3,5,19,20] to assess height.

There are few studies showing the associations between height, MUAC and waist curcumference[11,17]. The purpose of the present study was to assess relationships between height and arm span, waist circumference, sum of four skinfold thicknesses and MUAC among Ellisras rural children aged 8–18 years.

Methods

Geographical area

The rural areas of Ellisras are situated in the north-western region of Limpopo Province, South Africa. Approximately 50 000 people live there in forty-two settlements, which are 70 km from Ellisras town, now known as

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Lephalale, adjacent to the border with Botswana. Iscor coal mine and Matimba electricity power station are the two major sources of employment for many residents. The remaining workforce is involved in subsistence farming and cattle rearing, while a minority works in education or the civil service. Unemployment, poverty and low life expectancy seem to be more prevalent in this rural area[21].

Study population

The Ellisras Longitudinal Study (ELS) initially followed a cluster sampling method described previously by Monyeki et al.[22]. In brief, the study was undertaken at twenty-two schools (ten pre-schools and twelve primary schools) randomly selected from sixty-eight schools within Ellisras area[23]. For the purpose of the present analysis, data collected in November 2003 were used. The sample population comprised 1769 children (911 boys, 858 girls) aged 8–18 years.

The Ethics Committee of the University of Limpopo (Turfloop Branch) granted ethical approval prior to the survey and parents or guardians provided informed consent. The children and their parents signed assent forms after receiving verbal assent, which were translated into their mother tongue by the project's principal investigator.

Anthropometrics

All children underwent a series of anthropometric measurements according to the International Society for the Advancement of Kinanthropometry. Body mass was measured on an electronic scale to the nearest 0·1 kg. A Martin anthropometer was used to measure height to the nearest 0·1 cm. Skinfolds (suprailiac, subscapular, triceps and biceps) were measured three times using a Slim Guide skinfold calliper. Waist circumference and MUAC were measured with a flexible steel tape to the nearest 0·1 cm. Waist circumference was measured laterally midway between the lowest portion of the rib cage and the iliac crest, and anteriorly midway between the xiphoid process of the sternum and the umbilicus. Arm span was measured by positioning the participant's back against the wall with his/her arms spread against the wall at shoulder level and parallel to the floor with the palms facing forward. A steel tape was used to measure from the tip of the middle finger on one hand across the chest to the tip of the middle finger on other hand[24]. Participants below 8 years of age and above 18 years of age were of limited number. In order to make a meaningful conclusion to the study, participants were placed into age groups of 8–10 years, 11–14 years and 15–18 years.

Quality control

Training of all anthropometric measurements was done in compliance with standard procedures of the International Society for the Advancement of Kinanthropometry[24]. Reliability and validity of the anthropometric measurements are reported elsewhere[23]. In brief, the absolute and relative values for intra- and inter-tester technical error of measurement ranged from 0·04 to 4·16 cm (0·2 to 5·0 %) for height, from 0·01 to 0·02 kg (0 to 0·3 %) for body mass, from 0·2 to 6·0 mm (0·4 to 6·8 %) for skinfold measurements, and from 0 to 3·4 cm (0 to 4 %) for arm span and girth measurements (waist and MUAC).

Statistical analysis

Descriptive statistics were calculated for absolute body size. Student's t test was applied to test for significant differences between sexes. Pearson correlation coefficients were calculated to assess associations between height and arm span, waist circumference, MUAC and sum of the four skinfold thicknesses. Linear regression models were used to assess relationships between height and age, arm span, MUAC, waist circumference and sum of four skinfolds. All statistical analyses were done using the statistical software package SPSS version 10. The statistical significance was set at $P < 0·05$.

Results

Table 1 presents the descriptive statistics for age and anthropometric measurements of Ellisras rural children aged 8–18 years. Ellisras rural girls the age group of 11–15 years showed significantly higher mean values than boys for height, arm span, MUAC and waist circumference (all $P < 0·001$). Sum of four skinfolds was significantly ($P < 0·05$) higher in girls (range from 26·2 to 40·4 mm) than in boys (range from 24·0 to 26·2 mm) throughout all age groups. Mean height (range from 137·6 to 162·2 cm) was found to be higher than arm span (range from 125·7 to 157·4 cm) throughout all age groups for both Ellisras rural boys and girls, with the differences ranging from 4·0 to 11·5 cm.

Height and arm span showed a highly significant ($P < 0·001$) relationship (correlation coefficient ranging from 0·74 to 0·91) in both boys and girls throughout the age range (Table 2). The correlation between height and MUAC, waist circumference and sum of four skinfolds was low and significant ($P < 0·05$) in both Ellisras boys and girls, decreasing in magnitude in the older age group (correlation coefficient ranging from 0·15 to 0·47). The correlation (correlation coefficient ranging from 0·15 to 0·29) between height and sum of four skinfolds was low and significant ($P < 0·001$) in the older age groups (11–18 years). The correlation between height and age was not significant in the age group 8–10 years and 15–18 years for boys, while for girls in all age groups it was significant ($P < 0·05$; Table 2).

Table 3 illustrates the linear regression analysis of various anthropometric measurements and age as predictors of height for Ellisras rural children aged 8–18 years. The coefficient of determination of the models was high in the age group 8–10 years (84 % for boys and 75 % for girls) and 11–14 years (83 % for boys and 75 % for girls) and

Table 1 Descriptive statistics for age and anthropometric measurements of Ellisras rural children aged 8–18 years, Limpopo Province, South Africa, November 2003

| | 8–10 years | | | | 11–14 years | | | | 15–18 years | | | |
| | Boys (n 85) | | Girls (n 68) | | Boys (n 516) | | Girls (n 492) | | Boys (n 310) | | Girls (n 298) | |
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	10·2	0·59	10·3	0·51	13·3	1·13	13·3	1·13	15·9	0·60	15·9	0·62
Height (cm)	137·6	7·12	137·2	7·46	151·0**	9·25	153·2**	8·62	162·2	9·10	161·4	6·32
Arm span (cm)	127·2	8·67	125·7	7·97	142·6**	10·30	145·1**	10·55	155·8**	10·40	157·4**	8·02
Height – arm span (cm)	10·4	3·70	11·5	4·06	8·4	4·30	8·1	5·27	6·4**	6·90	4·0**	5·41
MUAC (cm)	16·7	1·26	16·8	1·72	18·3**	1·69	19·3**	2·25	20·0*	2·19	21·2*	2·37
Waist circumference (cm)	53·8	3·02	52·9	3·48	57·6**	4·47	58·1**	5·10	61·5	4·50	62·1	5·47
Sum of four skinfolds (mm)†	24·0*	5·04	26·2*	7·86	25·3**	6·98	34·1**	12·06	26·2**	8·30	40·4**	14·33

MUAC, mid-upper arm circumference.
*$P < 0.05$, **$P < 0.001$.
†Sum of triceps, biceps, suprailiac and subscapular.

Table 2 Pearson correlation coefficients between height and age and other anthropometric variables of Ellisras rural children aged 8–18 years, Limpopo Province, South Africa, November 2003

| | 8–10 years | | 11–14 years | | 15–18 years | |
	Boys	Girls	Boys	Girls	Boys	Girls
Age	0·10	0·28*	0·64**	0·61*	0·11	0·16**
Arm span	0·91**	0·86**	0·91**	0·87**	0·76**	0·74**
MUAC	0·56**	0·87**	0·54**	0·49**	0·47**	0·26**
Waist circumference	0·56**	0·53**	0·48**	0·46**	0·46**	0·23**
Sum of four skinfolds	0·18	0·29*	0·15**	0·29**	0·16**	0·15**

MUAC, mid-upper arm circumference.
*$P < 0.05$, **$P < 0.001$.

Table 3 Linear regression analysis of various anthropometric measurements and age as a predictor of height for Ellisras rural children aged 8–18 years, Limpopo Province, South Africa, November 2003

| | 8–10 years | | | | 11–14 years | | | | 15–18 years | | | |
	β	R^2	SEE	95 % CI	β	R^2	SEE	95 % CI	β	R^2	SEE	95 % CI
Boys												
Intercept	41·20**	0·84	2·97	24·90, 57·40	32·10	0·83	3·80	26·95, 37·34	74·01**	0·59	5·93	54·61, 93·41
Age	−0·659			−1·80, 0·50	0·687**			0·30, 1·07	−1·152*			−2·30, −0·01
Arm span	0·702**			0·61, 0·80	0·740**			0·69, 0·79	0·641*			0·56, 0·72
Waist circumference	0·074			−0·21, 0·36	−0·052			−0·15, 0·05	−0·011			−0·27, 0·25
MUAC	0·588			−0·13, 1·30	0·497**			0·17, 0·82	0·386			−0·18, 0·95
Sum of four skinfolds	0·002			−0·14, 0·14	−0·076*			−0·14, −0·02	−0·017			−0·12, 0·09
Girls												
Intercept	39·75**	0·75	3·37	17·06, 62·43	52·21**	0·75	4·30	46·14, 58·29	64·29**	0·56	4·21	49·56, 79·03
Age	−0·538			−2·47, 1·40	−0·023			−0·50, 0·46	0·705*			−0·09, 1·50
Arm span	0·755**			0·61, 0·90	0·723**			0·66, 0·78	0·615**			0·55, 0·68
Waist circumference	−0·144			−0·56, 0·27	−0·093			−0·22, 0·03	−0·177*			−0·32, −0·04
MUAC	0·995*			0·08, 1·91	0·086			−0·25, 0·42	−0·116			−0·48, 0·25
Sum of four skinfolds	−0·040			−0·19, 0·11	0·006			−0·04, 0·06	0·063*			0·01, 0·12

SEE, standard error of the estimate; MUAC, mid-upper arm circumference.
*$P < 0.05$, **$P < 0.001$.

decreased in the 15–18 years age group for both boys (59 %) and girls (56 %). Arm span was a significant ($P < 0.001$ or $P < 0.05$) predictor of height in all the age groups for both boys and girls, ranging from $\beta = 0.615$ (95 % CI 0·55, 0·68) to $\beta = 0.755$ (95 % CI 0·69, 0·90). Waist circumference, with a range from $\beta = −0.144$ (95 % CI −0·56, 0·27) to $\beta = −0.177$ (95 % CI −0·32, −0·04), and sum

of four skinfolds, ranging from $\beta = −0.040$ (95 % CI −0·19, 0·11) to $\beta = 0.063$ (95 % CI 0·01, 0·12), were statistically significant ($P < 0.05$) predictors of height in the 15–18 years age group for girls. MUAC, with $\beta = 0.497$ (95 % CI 0·17, 0·82), and sum of four skinfolds, with $\beta = −0.076$ (95 % CI −0·14, −0·02), were significant ($P < 0.05$) predictors of height in the 11–14 years age group for

boys (Table 3). Waist circumference was not a statistically significant predictor of height among boys in all the age groups.

Discussion

The present study was aimed at assessing the relationship between height and other anthropometric parameters of schoolchildren from rural areas of Ellisras, South Africa. Linear regression analysis revealed that arm span was a significant ($P < 0.05$) predictor of height in all age groups, while MUAC and sum of four skinfolds significantly predicted height in the 11–14 years age group for Ellisras boys. However, age could predict height in the 8–10 years age group for both boys and girls. Similar results were reported for Dhimals in West Bengal, India for children aged 10–18 years[7].

Longer mean height than arm span among Ellisras rural children was recorded in present study. Similar results were reported by Lucia et al.[6] for the four ethnic groups Oromo, Ambara, Tigre and Somali in Ethiopia. Furthermore, Yabanci et al.[10] reported shorter arm span compared with height among Turkish children aged 7–14 years. The results of the present study exhibit different trends from earlier reports. In Malawian children and Indian children arm span was found to be higher than height[7,11,25].

A significant strong correlation was recorded between height and arm span, waist circumference, MUAC and sum of four skinfolds in the present study among boys and girls. Similar trends were reported among Turkish children aged 7–14 years for height, arm span and MUAC[10]. In other studies too, height and arm span were reported to be strongly correlated[11,12,26].

Arm span was found to be an impressive predictor of height in the present study. Sum of four skinfolds was a significant ($P < 0.05$) positive predictor of height in the 15–18 years age group while waist circumference significantly ($P < 0.05$) negatively predicted height in the same age group for girls. Yabanci et al.[10] reported MUAC to be a predictor of height in the age group 7–10 years, while waist circumference was not a predictor of height for both sexes. Even though sitting height was reported to be a better predictor of total BMI[1,26], there has been no study showing the correlation between height and sum of four skinfolds.

The findings of the ELS do not differ with other investigations worldwide. In Montenegrins the use of arm span was very effective to determine the height of female and male communities in the surrounding areas, even though it may differ in ethnic and racial groups[18,27]. In all of the estimations of body height from various anthropometric measurements it is important to emphasize that arm span has been the most reliable indicator for predicting the body height of an individual[28]. Arm span can be a reliable method used to measure height for disabled, old aged and deformed individuals[11,29]. A study by Yabanci et al.[10] stated that MUAC and waist circumference were found to be moderately correlated with height, while previous work recommended the use of MUAC as a criterion standard that can be used to estimate height[30]. Others have argued that neither MUAC nor skinfold thickness has a good relationship ability with height[31].

Conclusion

In conclusion, arm span was found to be strongly related to height in schoolchildren aged 8–18 years from rural areas of Ellisras, South Africa, as reported in many studies. Sum of four skinfolds and waist circumference were found to be significantly associated with height in the older age group for girls. With waist circumference, however, the association was negative.

Acknowledgements

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