Coll. Antropol. **29** (2005) 2: 469–473
UDC 572.512.087-053.2(689.7)
Original scientific paper

Estimating Height from Arm Span Measurement in Malawian Children

Yuriy Zverev[1] and John Chisi[2]

[1] Department of Physiology, College of Medicine, University of Malawi, Blantyre, Malawi
[2] Department of Anatomy, College of Medicine, University of Malawi, Blantyre, Malawi

A B S T R A C T

Arm span and standing height were measured in 289 boys and 337 girls aged 6–15 years who were free from physical deformities which can affect stature or arm span. The arm span exceeded height in all age groups of boys and in older girls. At the age of 7, 11 and 12 years girls were significantly taller than the boys and had longer arm span while at the age of 15 years, the trend was opposite. The mean difference between the two anthropometric parameters for boys was 5.45±4.21 cm ($t=3.556$, $p<0.001$) and for girls was 4.94±4.96 cm ($t=3.542$, $p<0.001$). Correlation coefficient between height and arm span measurements for Malawian boys was 0.983 and for girls was 0.986. Height, arm span and height-arm span difference increased with age of children while height to arm span ratio decreased. The gender difference in height-arm span differences was only significant at the age of 15 years. Multiple regression and cross validation were performed. Height of Malawian children of both sexes can be estimated from equation:

Height (cm) = 15.756 + (0.168 x age) + (0.839 x arm span) (SEE=0.760, R^2=0.988).

Key words: *stature, arm span, children, Malawi, Africa*

Introduction

Estimates of body size such as height and weight are required for assessment of growth and nutritional status of children. Height measurements are also important for prediction and standardization of lung volumes as height is the best indicator of body size[1]. Therefore many equations for prediction of lung volumes include standing height. However some children and adults referred for spirometry have deformities of axial skeleton. Others are unable to stand as a result of neuromuscular weakness or other pathological conditions. In such patients height does not reflect the body size and use of height measurements in prediction equations is likely to produce errors. For example, in scoliotic patients, the predicted spirometric values were underestimated when the measured body height was used[2]. Under such circumstances, arm span is an alternative measure of body size.

Height may be estimated from arm span measurements by using regression equations or fixed correction factors[1–6]. Alternatively arm span can be directly substituted for height in patients who do not have limb deformities[6]. The last approach has obvious advantages as it does not require additional calculations. Several studies have indicated that use of arm span instead of height introduces small errors in prediction of lung volumes, which are not clinically important[7,8]. This might be correct for the populations with small differences between stature and arm span. However in Afro-Caribbean's and Malawians of both sexes, in Asian males, and Afro-American women arm span has been found to be significantly different from stature[5,9–11]. This suggests that arm span measurements might not be an appropriate proxy for height in some populations. In addition, the difference between 2 anthropometric parameters is affected by age and gender[5,6,8,12–15].

In children, both arm span and stature increase with age but the rates of increase in stature and arm span are different and depend on gender and ethnicity[12,13]. In adults, both anthropometric parameters decline with age and the rate of decrease in arm span is lower than age related decline in stature[14,15]. It has been demonstrated that the rate of age related decrease in height is higher in black populations than in white populations[15].

Received for publication August 9, 2004

Correlations between arm span and height have been reported for Caucasians, Asians, African Americans, Latin Americans and Afro-Caribbean's of different age groups[2–11]. Present study was conducted to address the dearth of available information on correlation between height and arm span measurements in African populations, particularly in children.

Methods

The study was conducted at St. Pius primary school located in Blantyre, Malawi. Population of Blantyre, which is the biggest industrial city in Malawi, is a mixture of the main tribes found in the country. The school was randomly selected from the list of governmental primary schools in Blantyre and to some extent it is typical for urban and semi-urban areas in Malawi. Sample size was estimated using 80% power at the 5% level of significance according to standard statistical procedure[16]. Children in study group were recruited using systematic sampling method. Each second pupil in each standard (of eight standards) was selected from the school registrar. Six hundred thirty eight children were approached. None of the selected pupils refused to participate in the survey. Twelve subjects (1.9%) who exhibited physical deformities, which can affect stature or arm span were excluded from the study population. In total, 289 boys and 337 girls between the ages 6 and 15 years participated in the study. 125 children (58 boys and 67 girls) were recruited in validation group from the same school using stratified sampling procedure. Both groups had similar age distribution of children and gender ratio. Prior to investigation permission was obtained from health and educational authorities. The purpose and procedure of the study was explained to children and their parents and informed consent was obtained from all pupils and their guardians. Ages of children were obtained from the schools register and reported to the nearest whole year. No attempt was made to assess pubertal status of older children due to the lack of appropriate conditions at school.

Children were seen in small groups at school in June 2001. Standing height and arm span measurements were done between 10 am and 12 noon by two trained observers. One observer took all height measurements and another measured arm span of all subjects with help from authors who made sure that the arms were straight during measurements. Standing height was measured on a barefooted children using a stadiometer (Invecta Plastics Ltd, UK) and method recommended by International Biological Programme[17]. Arm span was measured with a calibrated steel tape from the tips of middle fingers of maximally outstretched hands with subject standing and facing the wall[10,11]. Both measurements on each child were taken twice and recorded to the nearest mm. The mean value of each parameter was calculated if the two records for each variable agreed within 4 mm. When the two initial measurements did not satisfy the 4 mm criterion, two additional recordings were made and the mean of the three closest records was calculated. Similar procedure of calculation of the mean values of height and arm span was used in other studies[10,11].

The mean values of arm span, height, absolute difference between height and arm span measurements and height to arm span ratio were calculated separately for boys and girls according to the age group. Statistical analysis included descriptive statistics, single and multiple linear regression, paired t test and analysis of covariance. Prediction equations were developed with study group. Validation group did not participate in the development of the equations. For cross-validation of the equations, actual values of height were compared with predicted values using standard procedure[18,19].

Results

Tables 1and 2 show the means and standard deviations of height, arm span, absolute difference between arm span and height, and height to arm span ratio of Malawian children according to the age group. The mean arm span values exceeded height in all age groups of boys and in older girls. However in 6.8% of volunteers arm span was shorter than height. The mean difference between the two anthropometric parameters for the boys was 5.45±4.21 cm ($t=3.55$, $p<0.001$) and for the girls was 4.94±4.96 cm ($t=3.54$, $p<0.001$). Significant gender difference between mean values of height and arm span was observed in children aged 7, 11, 12 and 15 years (Table 3). At the age 7, 11 and 12 years the girls were significantly taller than the boys and had longer arm span while at the age of 15 years, the trend was opposite. Only at the age of 15 years significant gender difference was observed between height-arm span differences.

For both boys and girls, single linear regression analysis yielded straight lines (Figure 1). The difference between boys and girls in slopes and intercept values was not significant. Correlation coefficient between height and arm span measurements was 0.989 for both groups of children. The standardized residual plots indicated that the linear model of relationship between stature and arm span values was appropriate and adequate.

Analysis of covariance indicated that age had significant effect on height, arm span, and height to arm span ratio in the boys ($F=569.3$, $p=0.0000$; $F=474.6$, $p=0.0000$; $F=99.23$, $p=0.0000$ respectively) and in the girls ($F=653.0$, $p=0.0000$; $F=531.1$, $p=0.0000$; $F=99.2$, $p=0.0000$ respectively). Stature, arm span and stature-arm span difference increased with age of children while height to arm span ratio decreased. Multiple linear regression analysis revealed the following equations for prediction of height from stature measurements and age:

Height of boys =17.043 + (0.348 x age) + (0.815 x arm span) (SEE=0.689, R^2=0.983)

Height of girls = 18.158 + (0.265 x age) + (0.817 x arm span) (SEE=0,865, R^2=0,986)

TABLE 1
MEANS AND STANDARD DEVIATIONS OF ANTHROPOMETRIC PARAMETERS OF MALAWIAN CHILDREN

Age group	Boys					Girls				
	N	Height (cm)	Arm span (cm)	Height-Arm span difference	Height/ Arm span	N	Height (cm)	Arm span (cm)	Height-Arm span difference	Height/ Arm span
6	31	110.0±3.8	112.9±4.7	2.9±3.8*	0.974±0.033	39	110.8±5.4	112.2±6.0	1.4±4.2	0.988±0.038
7	33	118.2±5.1	121.3±6.5	3.1±2.9*	0.974±0.024	33	121.9±4.7###	124.1±4.2#	2.2±3.3	0.982±0.027
8	28	125.4±5.5	129.2±5.6	3.8±2.5*	0.971±0.020	39	126.4±6.5	131.0±8.9	4.6±6.8*	0.965±0.041
9	26	131.3±5.0	135.1±7.6	3.8±3.4*	0.972±0.024	30	131.2±7.1	135.1±8.1	3.9±3.6	0.971±0.026
10	31	134.0±7.7	138.7±9.5	4.7±3.6*	0.966±0.023	37	136.0±7.2	141.0±9.1	5.0±4.6*	0.965±0.028
11	30	136.5±6.3	141.9±8.3	5.4±4.2**	0.962±0.029	41	141.5±6.1###	147.2±6.9#	5.7±3.5***	0.961±0.023
12	27	140.8±5.6	146.5±7.3	5.7±3.1**	0.961±0.020	31	148.7±7.1###	154.2±8.7###	5.5±4.0**	0.964±0.025
13	25	148.1±6.0	154.9±7.1	6.8±3.0***	0.956±0.018	28	151.2±7.3	158.5±9.2	7.3±4.9***	0.954±0.028
14	27	155.9±7.4	164.8±8.7	8.9±3.4***	0.946±0.019	30	158.2±5.8	168.5±8.2	10.3±4.2***	0.939±0.023
15	31	162.9±6.1	173.4±8.6	10.5±5.5***	0.939±0.021	29	154.3±6.2###	162.0±8.1###	7.7±3.8***	0.952±0.022

*indicates differences between stature and arm span according to gender and age at *p<0.05, **p<0.01, ***p<0.001

#indicates gender difference between mean values of stature and arm span according to age at #p<0.05, ##p<0.01, ###p<0.001

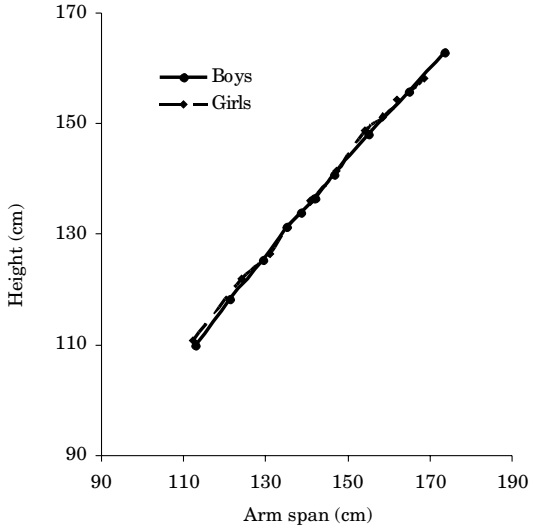

Fig. 1. The relationship between height and arm span in Malawian children.

TABLE 2
EQUATIONS FOR ESTIMATING HEIGHT FROM ARMS SPAN MEASUREMENTS AND AGE OF MALAWIAN CHILDREN

Variable	Coefficient	SE	t	p value
Boys Intercept	17.043	6.480	2.630	0.034
Age	0.348	0.517	0.673	0.522
Arm span	0.815	0.083	9.799	0.000
Girls Intercept	18.158	6.672	2.722	0.030
Age	0.265	0.476	0.557	0.595
Arm span	0.817	0.080	10.196	0.000
Total sample (boys+girls) Intercept	15.756	4.323	3.645	0.002
Age	0.168	0.326	0.515	0.613
Arm span	0.839	0.054	15.659	0.000

Gender difference between coefficients for age, arm span and intercept was not significant. Therefore two groups of children were combined together. The following equation was derived for combined sample:

$$\text{Height} = 15.756 + (0.168 \times \text{age}) + (0.839 \times \text{arm span})$$
$$(\text{SEE}=0.760,\ R^2=0.988)$$

In these equations age was expressed in years and arm span and height in centimeters. Data of the developed equations are shown in Table 2.

The final equation was cross-validated in the validation group. There was no significant difference (1.41±1.97 cm, p=0.383) between height measured and predicted. There was a high correlation between predicted height and measured height (R^2=0.917, p<0.0001, SEE=1.742). The correlation between measured and predicted height difference and measured height was significant (R^2=0.814, p<0.001).

Discussion

It has been demonstrated that a considerable proportion of normal spirometric data may be misinterpreted as obstructive or restrictive defects when arm span is directly substituted for height[4]. Therefore it is more appropriate to estimate height from arm span using regression equations[3–5,7–8]. However estimation of height from arm span measurement is not possible for most of African populations as correlation between these two anthropometric parameters is not known. Present study is the first attempt to establish relationship between the arm span and height in Malawian children aged between 6 and 15 years.

Arm span exceeded standing height in all age groups of Malawian boys and the difference between 2 anthropometric parameters increased with age from 2.9 cm in 6 year old boys to 10.5 cm in 15-year old boys. In Mala-

wian girls aged 6, 7 and 9 years, the difference between height and arm span was not statistically significant while in girls aged 8 years and 10 to 15 years arm span was longer than stature. The difference ranged from 4.6 cm in younger girls to 10.3 cm and 7.7 cm in 14 and 15 year old girls. An increase in height-arm span differences with age of children indicated higher growth rate of arm span compare to stature. The gender difference between mean values of height-arm span differences was only statistically significant in 15 year old children. The large differences between arm span and stature values in older Malawian children can not be attributed to systematic error in measurements because the standard procedures which minimize this type of errors were followed. It has been suggested that the large arm span-stature differences might reflect a clinical condition that differently affects the elongation of the trunk and the limbs in children[20]. However, it is unlikely, that the arm span of relatively large sample of Malawian children was affected but such rear condition as Marfan's syndrome which is characterized by disproportional elongation of extremities. In addition, the large difference between arm span and stature was also reported for Malawian adults[9]. This stature-arm span difference might be attributed to the fact that Malawian children and adults have generally shorter height than many other populations[21,22].

The pattern of stature and arm span relationship observed in Malawian children is different from the pattern described for Caucasian and Asian children. In white boys the mean arm span is always greater than stature[20] and the difference between the two parameters is higher than in girls. In younger white girls the arm span is longer than stature but in older girls it is exceeded by the height. In Korean children[23] the arm span to stature ratio is almost equal to 1.0 in the age groups 1 to 8 years. The arm span exceeds height at the age of 9 years and increases faster than height during puberty in both boys and girls. Due to the scarcity of published data on arm span in African children, it is not possible to compare Malawian children with other Africans. Comparison with a study on arm span of adult Malawians[9] indicated that younger children have lower differences between arm span and stature than adults. However this difference increase with age of children and 14 and 15 year old pupils have similar height-arm span difference with adults. The age and gender related ethnic differences in relation between height and arm span indicates that equations calculated for Caucasian or Asian children cannot be used for estimation of height from arm span measurements in Malawian children as they are likely to produce errors.

It has been demonstrated that correlation coefficient between height and arm span measurements for adult Malawian males was 0.871 and for females was 0.815[9]. In the present study correlation coefficient between arm span and height for Malawian boys was 0.983 and for girls was 0.986. This is remarkably similar to the 0.989 correlation for white Canadians[24], 0.903 correlation for white Americans[11] and 0.903 correlation for African Americans[11]. Strong and significant correlation between the two anthropometric parameters indicated that height can be predicted from arm span measurements in Malawian children. The goal of prediction equations is to estimate outcome for individuals not in the sample used in the analysis[18]. The final equation which we developed had a high R^2 and low SEE. When this equation was applied in the cross-validation group, there was small insignificant difference between measured and predicted height which indicated that the equation had good predictive qualities.

The equation for estimating height from arm span measurements in Malawian children differed from equations obtained in other groups of volunteers. Age of Malawian children was significantly associated with stature while the addition of age did not improve the regression model in group of Malawian adults. Gender difference between equations for children was not significant. Equations for Malawian adults had gender differences. Comparison of equations for Malawian children and Asian[13,23] and Caucasian[24] children demonstrated clear difference in slopes and intercepts which might be explained by ethnic differences in relations between arm span and standing height.

Conclusion

For the first time, correlation between arm span and stature has been established in Malawian children. Prediction equation calculated in this study might be used to estimate height of the children in whom height cannot be reliably measured.

Acknowledgements

Technical help from Mr. Gondwe and Mr. Kamadyaapa, who made all the measurements, is gratefully acknowledged.

REFERENCES

1. COTES, J. E.: Lung Function: Assessment and Application in Medicine, 5th Ed. (Blackwell Scientific Publication, Oxford, 1992). — 2. LEINDERHOLM, H., U. LINDGREN, Acta Orthop. Scand., 49 (1987) 469. — 3. AGGRAWAL, A. N., D. GUPTA, L. M. EZEKIEL, S. K. JINDAL, Indian J. Physio. Pharmacol., 44 (2000) 329. — 4. AGGARWAL, A. N., D. GUPTA, S. K. JINDAL, Chest, 115 (1999) 557. — 5. REEVES, S. L., C. VARAKAMIN, C. J. HENRY, Eur. J. Clin. Nut., 50 (1996) 398. — 6. TORRES, L. A., F. E. MARTINEZ, J. C., MANCO, Pediatr. Pulmonol., 36 (2003) 202. — 7. HEPPER, N. G. G., L. F. BLACK, W. S. FOWLER, Am. Rev. Resp. Dis., 91 (1965) 356. — 8. ALLEN, S. C., Age Aging, 18 (1989) 113. — 9. ZVEREV, Y. P., Ann. Hum. Biol., 30 (2003) 739. — 10. STEELE, M. F., Ann. Hum. Biol., 14 (1987) 445. — 11. STEELE, M. F., T. C. CHENIER, Ann. Hum. Biol., 17 (1990) 533. — 12. ŽIVIČNJAK, M., N. S. NARANČIĆ, L. SZIROVICZA, D. FRANKE, J. HRENOVIĆ, V. BISOF, Coll. Antropol., 27 (2003) 321. — 13. CHENG, J. C., S. S. LEUNG, B. S. CHIU, P. W. TSE, C. W. LEE, A. K., CHAN, G. XIA, A. K. LEUNG, Y. Y.

XU, J. Pediatr. Orthop., 18 (1998) 387. — 14. CLINE, M. G., K. E. MEREDITH, J. T. BOYER, B. BURROWS, Hum. Biol., 61 (1989) 415. — 15. MCPHERSON, J. R., D. R. LANCASTER, J. C. CARROLL, J. Gerontol., 33 (1978) 20. — 16. ARMITAGE, P., G. BERRY, Statistical Methods in Medical Research. (Blackwell Scientific Publications, Oxford, 1994). — 17. WEINER, J. S., J. A. LOURIE: Human Biology: a Guide to Field Methods. (Blackwell Scientific Publication, Oxford, 1969). — 18. OSBORNE, J. W., Practical Assessment, Research and Evaluation, 7 (2000) — 19. PORTNEY, L. G., M. P. WATKINS: Foundation of Clinical Research: Application to Practice. 2nd Ed (Prentice-Hall Incorporated, New Jersey, 2000) — 20. ENGSTROM, F. M., A. F. ROCHE, D. MUKHERE, D., Ann. Hum. Biol., 2 (1981) 19. — 21. PELLETIER, S. I., J. W. LOW, L. A. H. MSUKWA, Am. J. Hum. Biol., 5 (1996) 347. — 22. ZVEREV, Y., M. GONDWE, Ann. Hum. Biol., 28 (2001) 384. — 23. YUN, D. J., D. K. YUN, Y. Y. CHANG, S. W. LIM, M. K. LEE, S. Y. KIM, Ann. Hum. Biol., 22 (1995) 443. — 24. JARZEM, P. F., R. B. GLEDHILL, J. Pediatr. Orthop., 13 (1993) 761.

Y. Zverev

Department of Physiology, College of Medicine, University of Malawi, P.O. Box 360, Chichiri, Blantyre 3, Malawi
e-mail: yzverev@yahoo.com

PROCJENA VISINE NA OSNOVI MJERENJA RASPONA RUKU U MALAVIJSKE DJECE

S A Ž E T A K

Raspon ruku i stojeća visina izmjerene su u 289 dječaka i 337 djevojčica u dobi od 6 do 15 godina koji nisu imali nikakve fizičke deformacije koji bi utjecali na rast ili raspon ruku. Raspon ruku bio je veći od visine u svim dobnim skupinama dječaka i starijih djevojčica. U dobi od 7, 11 i 12 godina djevojčice su bile značajno više od dječaka i imale su duži raspon ruku, dok je u dobi od 15 godina trend bio obrnut. Srednja razlika između ta dva antropometrijska parametra za dječake je bila 5.45±4.21 cm ($t=3.556$, $p<0.001$), a za djevojčice 4.94±4.96 cm ($t=3.542$, $p<0.001$). Korelacijski koeficijent između visine i mjerenja raspona ruku u Malavijske djece bio je 0.983 za dječake i 0.986 za djevojčice. Visina, raspon ruku te razlika između visine i raspona ruku povećavali su se sa starošću djece, dok se omjer između visine i raspona ruku smanjivao. Spolne razlike u razlikama visine i raspona ruku bio je značajan jedino u dobi od 15 godina. Primijenjena je multipla regresija te analiza uz pomoć kontingencijskih tablica. Visina Malavijske djece obaju spolova može se procijeniti prema jednadžbi:

Visina (cm) = 15.756 + (0.168 x godine) + (0.839 x raspon ruku) (SEE = 0.760, $R^2 = 0.988$).