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RESEARCH

Arm-associated measurements as estimates of true height in black and white young adults of both genders: an exploratory study, Pietermaritzburg, KwaZulu-Natal, South Africa

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Objective: To determine the accuracy of arm-associated anthropometric measurements as estimates of true height.
Design: This was a cross-sectional descriptive survey.
Setting: The setting was Pietermaritzburg, KwaZulu-Natal, South Africa.
Subjects: The study population included a convenience sample (n = 200) of young adults aged 18 to 24 years, which included an equal number (n = 50) of white males and females, and black males and females.
Outcome measures: The following measurements were taken in accordance with international standards for anthropometric kinanthropometry: (i) stretch stature; (ii) armspan; (iii) half-armspan; and (iv) demi-span. Adjustment equations used to convert arm-associated measurements to true height included that of the World Health Organization equation, half-armspan multiplied by two and, the demi-span equation.
Results: None of the existing height estimation equations accurately predicted true height in the study sample. Significant differences in the accuracy of estimates were also measured between race groups ($p < 0.001$) and for gender ($p < 0.001$). In black males the demi-span male-specific equation provided results that did not differ from true height, as was also the case for armspan in white males. Black females and white females had identical outcomes where all height estimates differed significantly from true height.
Conclusion: Findings indicate the need for gender and race-specific height estimation methods. It would seem that armspan is suitable for use in white males and demi-span male equation suitable for use in black males. None of the height estimation methods accurately predicted true height in females.

Keywords: anthropometry, arm-associated measurements, height estimates, population-specific methodology, stretch stature

Introduction

The stretch stature method is the gold standard for measuring true height.[1] The ability to stand upright is not always possible and therefore calls for the use of indirect height estimation methods.[2,3] Common body parameters that have been used in calculating true height include knee height, armspan, half-armspan and recumbent height.[2,3] It is apparent that clinicians use height estimation methods without taking into consideration possible factors that might influence the outcome, such as population and race differences. Such practices hold especially true in a local setting. The only available research publication describes knee height as a surrogate measure of true height in a group of South Africans older than 60 years.[4]

The lack of data that describe the accuracy of available height estimation calculations within the South African population is what motivated this study, which was used to investigate arm-associated calculations of true height among local black and white young adults of both genders. The null hypothesis was that there would be no difference in estimates of true height calculated from armspan, half-armspan multiplied by two (x 2), the existing demi-span equation and the World Health Organisation (WHO) equation when compared with true height of black and white young adults of both genders.

Methods

Subjects

A convenience sample (n = 200) of equal numbers of consenting young white male and female, and black male and female volunteers aged 18 to 24 years were recruited to participate in this study. Volunteers had to be free from any skeletal abnormalities, able to stand erect unaided and have no amputations that could influence the accurate measurement of stretch stature or armspan.

Setting

The study setting was the University of KwaZulu-Natal campus grounds in Pietermaritzburg, KwaZulu-Natal, South Africa.

Study design

A cross-sectional quantitative descriptive survey study design was employed. All anthropometric measurements, including stretch stature, armspan, half-armspan and demi-span were measured by three trained fieldworkers using the International Standards for Anthropometric Kinanthropometry (ISAK).[1] Each measurement method was conducted by the same fieldworker. The methodology for conducting stretch stature and arm-associated height estimation methods is summarised in Table 1. Where necessary, measurements were made using the right side of the body.[1] All measurements were

Table 1: Summary of measurement methodology.

Estimate	Method	Ref
Stretch stature	Subject stood without shoes, with heels, buttocks and upper back touching the stadiometer. The head was placed in a Frankfort plane. One recorder placed one hand on either side of the subject's jawline to position the head and apply 'upward pressure' into the mastoid processes. The other recorder asked the subject to take a deep breath and hold it, while the head board was placed onto the vertex (top of the head)	Marfell-Jones[1]
Armspan	Subject stood without shoes, with heels, buttocks and upper back touching a wall with an even surface. Both arms were simultaneously placed in a horizontal plane in line with shoulders with arms at a 90° angle in relation to the body. Arms were outstretched laterally, with palms facing outwards. Two fieldworkers stood on either side of the subject, holding a non-elastic measuring tape flat against the wall. Fieldworkers subsequently measured armspan by measuring the distance from the dactylion (tip of middle finger) on the left hand to the dactylion of the right hand	Marfell-Jones[1], Mahan et al.[5]
Half-armspan x 2	A similar body position to that reported for armspan was used for measuring half-armspan. The difference in measurement taken was that the distance spanned from the dactylion of the right hand to the suprasternal notch (on the mid-sternal line) using non-elastic tape. The mean value obtained was multiplied by two to provide an estimate of height, based on armspan	Marfell-Jones[1], Kwok and Whitelaw[6], Beghetto et al.[7], Hickson and Frost[8]
WHO equation	The WHO height estimation equation was used to calculate height for both gender by using the mean value obtained from half-armspan according to the following equations: Height (cm) = [0.73 x (2x half-armspan (cm)) + 0.43]	World Health Organization[9]
Demi-span equation	A similar body position to that reported for armspan and half-armspan was used for measuring demi-span. The latter refers to the distance from the root of the middle finger to the suprasternal notch. Hence, this measurement was taken by measuring the distance from the dactylion to the root of the right middle finger. The mean of the value obtained was subtracted from the mean of the value recorded for half-armspan by means of the following equation: Demi-span = [Half-armspan — (distance between dactylion and root of the middle finger)] Values recorded for demi-span were then imported into the following gender-specific equations to calculate height: Females: Height (cm) = [1.35 x demi-span (cm)] + 60.1 Males: Height (cm) = [1.40 x demi-span (cm)] + 57.8	Bassey[10], Preddy[11]

performed in triplicate and recorded to the nearest 0.1 cm. The mean of the two closest values was captured.

A pilot study was conducted on a convenience sample (n = 10) of young adult black (n = 5) and white volunteers (n = 5) of both genders with inclusion and exclusion criteria similar to those of the main study. The pilot study was used to test the plausibility of the research question and also for standardisation of anthropometric measurement techniques between fieldworkers.

Ethics approval was granted by the University of KwaZulu-Natal Human and Social Science Research Ethics Committee. Prior to data collection, the purpose of the study was explained to each participant and all were required to sign an informed consent form.

Statistical analysis

The Statistical Package for Social Sciences (SPSS®) version 21 (2012) (IBM Corp, Armonk, NY, USA) was used to perform the statistical analysis. The half-armspan measurements were used in two calculations: (i) half-armspan multiplied by two; and (ii) the WHO equation.[6,9] The demi-span measurements were used in the gender-specific Bassey formulae.[10] Statistical comparisons were made by race and gender and for each estimated variable, compared with the true height measurement.

Results

Sample characteristics

The study sample (n = 200) included an equal number of white male and female, black male and female volunteers, respectively. The mean age of the subject group was 20.9 ± 1.6 years.

Comparison of true height with estimates thereof

Table 2 provides an overview of the comparison of true height versus estimates thereof for the group as a whole, regardless of gender. Significant differences ($p < 0.001$) between true height and estimates thereof were measured. The equations that used armspan and half-armspan significantly overestimated true height whereas the WHO equation consistently underestimated true height. These differences were measured in the study group as a whole, as well as within each race, apart from the use of armspan in calculating height that did not differ significantly from true height in white subjects. A comparison between black and white subjects by means of the independent samples t-test also yielded significant differences ($p < 0.001$) in the extent to which armspan and half-armspan overestimate true height, while the WHO equation underestimated true height in black subjects. In white subjects the same arm-associated estimates under- and over-estimated true height respectively, while the WHO equation also underestimated true height.

Table 2: Comparison of measured height to estimates thereof for the study sample as a whole, according to race and between race groups.

Variable (cm)	Mean± SD	*p*-value	Interpretation
Stretch stature minus armspan	−1.57 ± 5.00	0.000*	↑
Stretch stature minus half-armspan x 2	−5.34 ± 5.35	0.000*	↑
Stretch stature minus WHO equation	41.31 ± 4.88	0.000*	↓
Black study sample (*n* = 100)			
Stretch stature minus armspan	−4.15 ± 3.74	0.000*#	↑
Stretch stature minus half-armspan x 2	−7.71 ± 4.26	0.000*#	↑
Stretch stature minus WHO equation	38.57 ± 3.71	0.000*#	↓
White study sample (*n* = 100)			
Stretch stature minus armspan	1.00 ± 4.78	0.9038*#	↓
Stretch stature minus half-armspan x 2	−2.97 ± 5.30	0.000*#	↑
Stretch stature minus WHO equation	44.05 ± 4.35	0.000*#	↓

Note: *p*-value calculated as level of significance at $p < 0.05$.
*Analysis of variance.
#Independent samples t-test.

Table 3: Comparison between true height and estimates thereof by race.

Variable (cm)	Race	*n*	Mean ± SD	Median difference	*p*-value*
Stretch stature	Black	100	165.29 ± 8.58	−7.47	0.000
	White	100	172.77 ± 9.25		
Armspan	Black	100	169.44 ± 10.00	−2.32	0.117
	White	100	171.76 ± 10.82		
Half-armspan	Black	100	86.50 ± 4.96	−1.37	0.069
	White	100	87.87 ± 5.59		
Demi-span	Black	100	78.61 ± 4.57	−1.42	0.042
	White	100	80.03 ± 5.22		
Half armspan x 2	Black	100	173.00 ± 9.92	−2.73	0.069
	White	100	175.74 ± 11.19		
WHO equation	Black	100	126.72 ± 7.24	−2.00	0.069
	White	100	128.72 ± 8.17		

*Independent samples t-test; level of significance at $p < 0.05$.

Comparison of true height and estimates thereof between race groups

In Table 3, a comparison between black and white subjects in terms of true height and arm-associated estimates of true height is reported. Results reported in Table 3 indicate that white subjects were significantly taller than black subjects ($p < 0.001$). However, a comparison between estimates of true height between race groups indicated demi-span to be the only estimate that yielded a significant difference when used for the calculation of true height ($p = 0.042$).

Comparison of true height and estimates thereof between genders

In Table 4, a comparison between males and females in terms of true height and arm-associated estimates of true height is reported. The comparison between estimates of true height between genders indicated all arm-associated estimates of true height to yield a significant difference when used for the calculation of true height ($p < 0.001$). Male volunteers were found to have significantly larger stretch stature and arm measurements when compared with female subjects ($p < 0.001$).

Comparison of true height and estimates thereof for males and females according to race

In Table 5, a comparison between black and white volunteers of by gender for true height and arm-associated estimates of true height is reported. The comparison between estimates of true height by gender of both races indicated that the best estimate of true height for black male volunteers was the demi-span equation ($p = 0.306$), whereas armspan ($p = 0.995$) provides the best estimate for white male volunteers (the difference between the true height and estimate was not significant); however, none of the arm-associated estimates of true height seemed to be reliable when used for the calculation of true height in black and white females.

Discussion

Considering the variety of existing equations that estimate true height, such as the height estimation equation developed by the

Table 4: Comparison of true height and estimates thereof by gender.

Variable (cm)	Gender	Mean ± SD	Median difference	*p*-value*
Stretch stature	Male	175.45 ± 7.49	12.83	0.000
	Female	162.61 ± 6.95		
Armspan	Male	177.93 ± 7.55	14.65	0.000
	Female	163.28 ± 7.37		
Half-armspan	Male	90.77 ± 4.00	7.18	0.000
	Female	83.60 ± 3.84		
Demi-span	Male	82.61 ± 3.77	6.60	0.000
	Female	76.02 ± 3.60		
Demi-span equation	Male	173.46 ± 5.28	[a]	[a]
	Female	162.73 ± 4.87		
Half arm span x 2	Male	181.55 ± 8.01	14.35	0.000
	Female	167.19 ± 7.69		
WHO equation	Male	132.96 ± 5.84	10.48	0.000
	Female	122.48 ± 5.61		

*Independent samples t-test; level of significance at $p < 0.05$.
[a]Gender-specific equation.

Table 5: True height and estimates thereof by race and gender.

Variable (cm)	Mean ± SD	*p*-value*	↓ or ↑
Black males ($n = 50$)			
Stretch stature minus armspan	−4.96 ± 3.13	0.000	↑
Stretch stature minus half-armspan x 2	−8.17 ± 4.54	0.000	↑
Stretch stature minus WHO equation	39.92 ± 3.89	0.000	↓
Stretch stature minus male demi-span equation	−0.60 ± 4.10	0.306	↑
Black females ($n = 50$)			
Stretch stature minus armspan	−3.34 ± 4.14	0.000	↑
Stretch stature minus half-armspan x 2	−7.25 ± 3.95	0.000	↑
Stretch stature minus WHO equation	37.22 ± 2.99	0.000	↓
Stretch stature minus female demi-span equation	−3.03 ± 3.06	0.000	↑
White males ($n = 50$)			
Stretch stature minus armspan	0.00 ± 4.97	0.995	↓
Stretch stature minus half-armspan x 2	−4.04 ± 5.43	0.000	↑
Stretch stature minus WHO equation	45.05 ± 4.40	0.000	↓
Stretch stature minus male demi-span equation	4.57 ± 4.42	0.000	↓
White females ($n = 50$)			
Stretch stature minus armspan	2.00 ± 4.39	0.002	↓
Stretch stature minus half-armspan x 2	−1.91 ± 4.99	0.009	↑
Stretch stature minus WHO equation	43.04 ± 4.10	0.000	↓
Stretch stature minus female demi-span equation	2.81 ± 4.14	0.000	↓

Notes: ↑ Overestimates height compared with stretch stature. ↓ Underestimates height compared with stretch stature.
*Independent samples t-test; level of significance at $p < 0.05$.

World Health Organization,[9] these height equations have often been categorised as universal equations to be used globally. This ‘one size fits all’ approach to anthropometry in recent studies has been shown to be questionable, with studies linking differences in outcomes to ethnicity, age, gender etc. This phenomenon was evident in this study using young adult South African volunteers where the arm-associated estimates of true height yielded values that differed significantly from the true height ($p < 0.001$). None of the arm-associated height estimation equations used in this study accurately predicted true height in the study population as a whole. Therefore, the null hypothesis that there is no difference between true height and arm-associated estimates thereof has been rejected.

These findings were supported by other African and international studies, which investigated the use of true height estimates in various population groups of different ethnicities and age groups.[7,12–15] The study results highlight the need for gender and ethnicity to be considered in the calculation of true height. These ethnic differences were evident in the current study, such as where the stretch stature was significantly different ($p < 0.001$) between black and white volunteers, as well as when compared between the arm-associated estimates thereof ($p < 0.001$). In black males, the demi-span male-specific equation provided results that did not differ significantly from true height, as was also the case for the armspan equation in the white male groups. In the black female and white female groups the estimates yielded similar outcomes when compared with true height. This therefore underlines the need for race-specific and gender-specific anthropometric equations, which has been supported by the findings of several international height studies.[2,7,12,15–17]

The South African population is highly diverse in terms of ethnicity. Anthropometric measurements form part of health surveillance, clinical investigations and growth monitoring, which eventually translate into public health intervention and/or individual treatment. Unfortunately, it is not always possible to directly measure stretch stature and therefore the use of estimates of true height is required. These equations should be validated prior to use in each specific population, so as to determine which equation is accurately predictive of true height.

Limitations

Convenience sampling was used, which may result in potential bias when compared with random sampling methods. Where the accuracy of data may have been compromised, this would have the potential to affect the results generated. However, the authors aimed to improve the validity and reliability of the data by training the fieldworkers, standardising the methodology by conducting a pilot study and having the same fieldworker measure the same measurement across the study sample.

Conclusion

The findings from this study emphasise the importance for gender-specific and race-specific height estimation equations for the South African population. It would seem that armspan used in the estimation of true height is suitable for use in the white male population and the demi-span equation is suitable for use in the black male population. None of the height estimation methods accurately predicted true height in females. It is therefore important that the current study is repeated on a large scale, in order to develop adopted equations for different ethnic backgrounds and age groups that would provide an accurate estimate of true height.

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References

1. Marfell-Jones M. International standards for anthropometric assessment. Australia: ISAK; 2001.
2. Shahar S, Pooy NS. Predictive equations for estimation of stature in Malaysian elderly people. Asia Pac J Clin Nutr. 2003;12:80–4.
3. Froehlich-Grobe K, Nary DE, Van Sciver A, et al. Measuring height without a stadiometer. Am J Phys Med Rehab. 2011;90(8):658–66.
4. Marais ML, Marais D, Labadarios D. Assessment of nutritional status of older people in homes for the aged in Somerset West area. South Afr J Clin Nutr. 2007;20(3):102–8.
5. Mahan LK, Escott-Stump S, Raymond JL. Krause's food & the nutrition care process. 13th ed. Missouri: Saunders; 2012.
6. Kwok T, Whitelaw MN. The use of armspan in nutritional assessment of the elderly. J Geriatr Surg. 1991;39:492–6.
7. Beghetto MG, Fink J, Luft VC, et al. Estimates of body height in adult inpatients. Clin Nutr. 2006;25:438–43.
8. Hickson M, Frost G. A comparison of three methods for estimating height in the acutely ill elderly population. J Hum Nutr Dietet. 2003;16:13–20.
9. World Health Organization. Management of severe malnutrition: a manual for physicians and other senior health workers. Geneva: WHO; 2009.
10. Bassey EJ. Demi-span as a measure of skeletal size. Ann Hum Biol. 1986;13(5):499–502.
11. Preddy VR. Handbook of anthropometry, Volume 1: Part 1-6. New York, NY: Springer; 2012.
12. Golshan M, Amra B, Hoghoghi MA. Is arm span an accurate measure of height to predict pulmonary function parameters? Monaldi Arch Chest Dis. 2003;59(3):189–92.
13. Fatmah F. Predictive equations for estimation of stature from knee height, arm span, and sitting height in Indonesian Javanese elderly people. Int J Med Sci. 2009;10:456–61.
14. Popovic S, Bjelica D, Slavko M, et al. Body height and its estimation utilizing arm span measurements in Serbian adults. Int J Med Sci. 2013;31:271–9.
15. de Lucia E, Lemma F, Tesfaye F, et al. The use of armspan measurement to assess the nutritional status of adults in four Ethiopian ethnic groups. Eur J Clin Nutr. 2002;56:91–5.
16. Mohanty SP, Babu SS, Nair NS. The use of arm span as a predictor of height: a study of south Indian women. J Orthop Surg. 2001;9:19–23.
17. Capderou A, Berkani M, Becquemin M-H, et al. Reconsidering the arm span–height relationship in patients referred for spirometry. Eur Respir J. 2011;37:157–63.

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