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The Use of Arm Span as a Substitute for Height in Calculating Body Mass Index (BMI) for Spine Deformity Patients*

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Abstract

Objective: To compare arm span and height in body mass index (BMI) calculation in patients with spinal curvature and investigate their impact on interpretation of BMI.
Study Design: Prospective case-control cohorts.
Summary of Background Data: The BMI value is based on weight to height ratio. Spine deformity patients experience height loss and its use in calculating BMI is likely to produce errors. A surrogate for height should therefore be sought in BMI determination.
Methods: Ninety-three spine deformity patients were matched with 64 normal children. Anthropometric values (height, arm span, and weight) and spinal curve were obtained. BMIs using arm span and height were calculated, and statistical analysis performed to assess the relationship between BMI/height and BMI/arm span in both groups as well as the relationship between these values and Arm Span to Height difference (Delta AH).
Results: There were 46 males and 47 females, the average age was 15.5 years in Group 1 versus 33 males and 31 females, average age 14.8 years in Group 2. Major scoliosis in Group 1 averaged 125.7° (21° to 252°). The extreme curves show vertebral transposition, with overlapping segments making it more than 180°. A logistic regression showed that there was linearity in BMI scores ($R^2 = 0.97$) for both arm span and height ($R^2 = 0.94$) in group 2 patients. For group 1 patients there was a significant difference in the BMI values when comparing BMI/arm span versus BMI/height ($p < .0001$). Mean BMI values using height was overstated by 2.8 (18.6%). The threshold at which BMI score must be calculated using arm span as opposed to the height (Delta AH) was determined to be 3 cm.
Conclusions: Spine deformity patients experience height loss, which can impact their true BMI values thereby giving an erroneous impression of their nutritional status. The arm span should be used in patients with Delta AH >3 cm to properly assess nutritional status.
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Keywords: BMI; Arm span; Height; Spine deformity; Nutrition assessment

Introduction

Body composition mirrors the nutritional status in growing children and young adults. The values for height and weight are required to assess growth and nutritional status [1,2].

There are direct methods of assessing body composition such as dual x-ray absorptiometry, computed tomography, and magnetic resonance imaging [3]. However, they are expensive and not easily accessible in most developing and underdeveloped countries [2].

Body mass index (BMI) is an anthropometric indicator based on the weight to height ratio [4]. It is a reliable indicator of body fatness and the preferred indicator of body thinness to classify malnutrition [4-6]. Studies have shown that BMI does not measure body fat directly however it correlates to direct measures of body fat [7]. BMI threshold that will classify an individual below 20 years to be undernourished differs with age and gender. The WHO growth standard classification of underweight in boys is between ≤13.75 to 17.50 and girls ≤12.75 to 16.50 [8].

Height is known to be a significant parameter in the assessment of nutritional status and maturity [2,9]. However, in children and young adults with spinal deformities such as

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kyphosis and scoliosis, height does not reflect the true body size and the use of height measurement in predictive equations such as BMI is likely to produce errors [2].

Presently, there are no guidelines on the degree of spinal curvature or height loss beyond which the measurement of height would be invalid in BMI calculation, and the threshold for height loss when BMI calculation can lead to misclassification of malnutrition in growing children and young adults. Alternative anthropometric indicators that are used when body height cannot be determined are therefore very important in predicting age-related nutritional deficiency in individuals whose skeletal condition makes it impossible to measure their precise height.

Body height in such cases is then estimated from reliable anthropometric indicators such as hand and foot length, sitting and knee height, length of sternum, vertebral column length, and arm span [10,11].

Arm span is the physiological measurement with the closest correlation to standing height. It has been used in place of height either by direct substitution or by application of a fixed correction factor based on arm span–height ratio or by regression equation [12,13]. Direct substitution has been mostly favored with errors that are not clinically important.

Monyeki and Sekhotha [9] established correlation between arm span and height in Ellisras rural children aged 8–18 years. Their correlation was similar to that of Turkish children aged 7–14 years and Oromu, Ambara, Tigre, and Somali ethnic groups in Ethiopia [14].

Another study among south Indian women showed that arm span was the most reliable body parameter for predicting height of an individual [15]. However, the study suggested the need to develop separate models for each population on the account of ethnic and racial differences. Thus, arm span and body height have been found to vary in different ethnic and racial groups.

Using standing height to calculate BMI in patients with spinal deformity could be inappropriate because of the reported height loss. A simple and reliable measure of height in such patients is necessary. Several studies are available that use arm span to derive height in pulmonary function test (PFT) calculations. In assessing true nutritional status there have been many experiences of physical findings not tallying with anthropometric measurement. This informed the need to find a more accurate measure for the BMI as it is one of the major assessment tools in determining nutritional status. However, very limited data are available when calculating the true BMI to determine the nutritional status of individuals with spine deformity.

The target population in our study was the spine deformity patients who were evaluated at the FOCOS Hospital in 2014 and first quarter of 2015. These patients hailed from different nationalities, including Ethiopia, Sierra Leone, Ivory Coast, Nigeria, and Ghana. The majority of these patients came to the hospital with signs of severe malnutrition. For an overall successful surgery, a good nutritional status is required. An assessment was done on each patient at initial presentation to ascertain his or her caloric, protein, and other nutrient needs, and a nutritional intervention plan was developed. Surgery was scheduled after they have met their specific nutritional targets. This study compared the use of arm span and height in BMI calculation in patients with severe spinal deformities and investigated the impact on interpretation of BMI.

Materials and Methods

Study population

Pediatric patients scheduled to undergo spine deformity surgery at the FOCOS orthopedic hospital in Accra Ghana were enrolled in the study. The nutrition and dietetic department of the hospital assessed the patients and provided nutrition intervention methods. Patients with pathologies such as poliomyelitis or paralysis were excluded.

A comparison group of healthy children and teenagers without spine deformity were enrolled from a local junior and senior high school in Accra Ghana. The groups were matched by age and gender. Students who had any lower limb deformity or spine deformity were excluded. Informed consent was obtained from the students and parents. Age, gender, and country of origin were recorded. The study was approved by the Noguchi Memorial Institute for Medical Research institutional review board.

Anthropometry

Weight was measured on an electronic scale (Omron BF 511) to the nearest 0.1 kg. A nonstretchable tape measure was used to measure height to the nearest 0.1 cm.

Arm span was measured using standard methods with a steel tape. Participants were positioned back against the wall with arms spread against the wall at shoulder level and parallel to the floor with the palms facing forward. The measurement from the tip of the middle finger on one hand to the tip of the middle finger on other hand was recorded.

The height, arm span, and weight were measured for all participants in the control group, after their backs were checked for any spine deformity. A scoliometer was used on each subject's back, and where the angle of rotation recorded was 5° and above the participant was disqualified. The same measurements were taken among the study group cases and recorded.

BMI calculation was performed using both the height and arm span values with the standard formulae

H-BMI (H) and A-BMI

Statistical Analysis

Arm span BMI and height BMIs were calculated for both groups, and a linear regression was done between groups. Paired *t* test was conducted among the control group to compare height and arm span. Paired *t* test was also done to compare the BMIs computed with the height and that computed with arm span among cases and control. Pearson correlation coefficients were calculated to assess associations between height and arm span. Linear regression models were used to assess relationships between Height BMI and Arm span BMI. The relationship between BMI/arm span and BMI/height and arm span to height difference (delta AH) was analyzed to determine the point at which a spine deformity affects the true height of a person. All statistical analyses were done using the statistical software package SPSS version 10. The statistical significance was set at $p < .05$.

Results

One hundred fifty-seven children and teenagers were recruited over the period of the study. Ninety-three spine deformity patients met the inclusion criteria. They were matched with sixty-four normal children. There were 46 males and 47 females, average age 15.4 years, in the study group (Group 1) versus 33 males and 31 females, average age 14.8 years in the control group (Group 2). Major scoliosis in Group 1 averaged 125.7° (21° to 252°). Tables 1-4 presents the descriptive statistics for age, sex, and nationality.

Paired *t* test was conducted among Group 2 to compare height and arm span. The mean height was 160 cm, standard deviation (SD) 14.1 as compared with mean arm span of 163 cm, SD 15.8 ($p < .05$). A paired *t* test was conducted to compare the BMIs computed with the height (21.2) and that computed with arm span (20.1) (Table 5). There was no statistically significant difference in the scores of Height BMI (M = 21.2, SD = 4.4) and arm span BMI (M = 20.1, SD = 4.1) in the control group. Nevertheless, the real mean difference was 1.1. The difference is not substantial in terms of BMI, and hence the arm span BMI was comparable to Height BMI among the control group. A logistic regression showed that there was linearity in BMI scores (R^2 = 0.97)

Table 1
Age.

	Group	N	Standard deviation	Mean	Minimum	Maximum
Age (years)	1	93	15.5	5.3	3	25
	2	64	14.8	4.4	5	24

Table 2
Group 1.

Sex	Nationality			Total
	Ethiopia	Ghana	Sierra Leone	
Female	37	4	6	47
Male	38	0	8	46

Table 3
Group 2.

Sex	Nationality			Total
	Nigeria	Ghana	Ivory Coast	
Female	0	30	1	31
Male	1	32	0	33

Table 4
Nationality.

Nationality	n	Percent
Ghana	66	42.04
Ethiopia	75	47.77
Sierra Leone	14	8.92
Nigeria	1	0.64
Ivory Coast	1	0.64

Table 5
Paired sample *t* test for height BMI and arm span BMI among the control group.

Paired samples statistics			
	Mean	N	Standard deviation
Height BMI	21.20	64	4.40
Arm span BMI	20.10	64	4.10

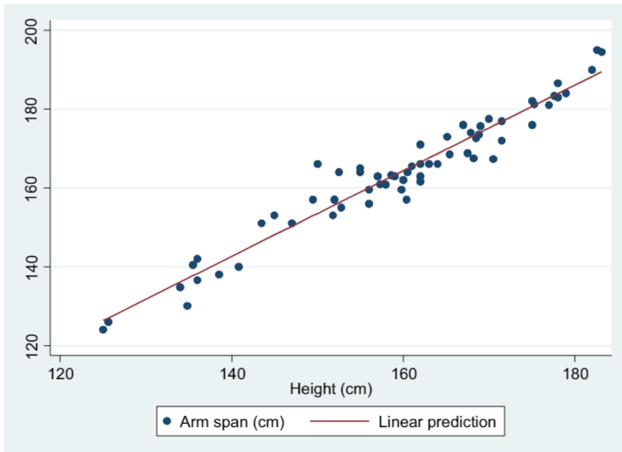


Fig. 1. Linear relation in Group 2.

Table 6
Paired sample *t* test for height BMI and arm span BMI among the study group.

Paired samples statistics			
	Mean	N	Standard deviation
Height BMI	18.1	93	3.1
Arm span BMI	15.3	93	2.8

BMI, body mass index.

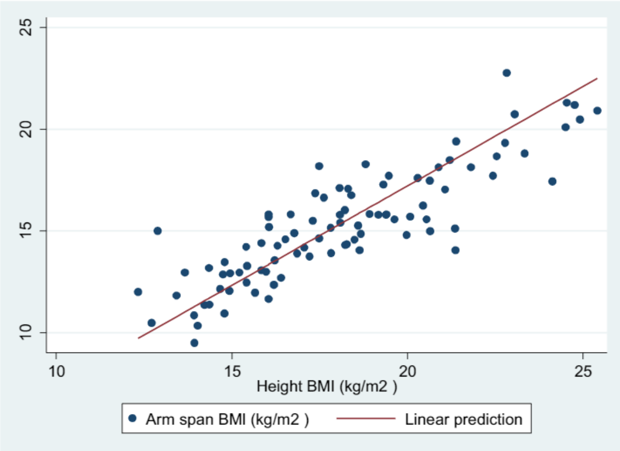


Fig. 2. Weak linear relation in Group 1.

Table 7
Height arm span threshold.

Delta AH	p value
0–2 cm	.1463
0–3 cm	.0312
0–4 cm	.0005
0–5 cm	.0001

(Fig. 1) and that arm span could be used as a proxy to height ($R^2 = 0.94$) in persons with normal spines (Group 2). These findings suggest that in normal individuals, arm span and height are very similar and therefore BMIs computed with arm span completely reflect height BMI. A paired *t* test was conducted among Group 1 to compare the height and arm span scores (Table 6).

There was a statistically significant difference in the height (M = 137.4, SD = 16.7) and arm span (M = 149.8, SD = 19.8) in this group ($t = -13.5$, $p < .05$). The difference between the height and arm span was about 12.4 cm, indicating an apparent decrease in height. These findings suggest that in individuals with spinal deformities—as in the case of the experimental group—the height is compromised, hence making arm span significantly higher than the height.

Subsequently, paired *t* test was conducted to compare BMI estimates using height and arm span. There was a statistically significant difference between the computed height BMI (M = 18.1, SD = 3.1) and the arm span BMI (M = 15.3, SD = 2.8) among the study subjects ($t = 13.73$, $p < .05$). The mean difference between height BMI and arm span BMI was 2.8.

Moreover, there was a weak linear relation in patients with spine deformity (Group 1) (Fig. 2). Further analysis showed that the threshold value at which the BMI scores for Height and Arm span differed was 3 centimeters (Delta AH ⩾3 cm) (Table 7).

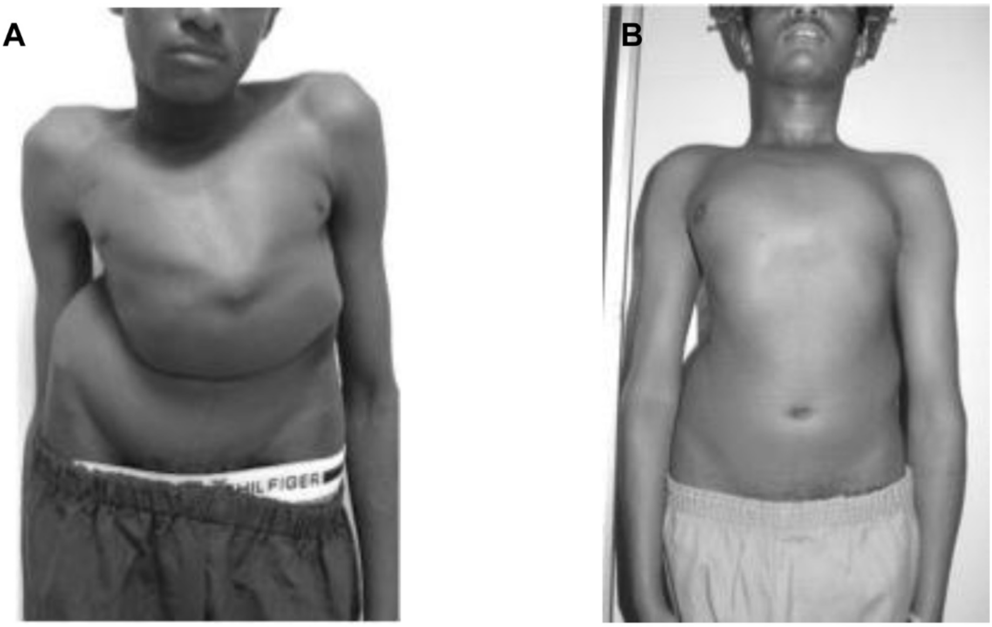
These findings suggest that in circumstances where true height cannot be determined—as in the case of individuals with spinal deformities—Arm span BMIs can be used for assessment instead of the height BMI when Delta AH is greater than 3 cm.

Discussion

Height estimations using different physical measurements have been studied by a number of authors [16,17]. In nutritional assessment of patients with deformity little has been done to correct compromised height which eventually has a negative effect on the calculation of BMI. This study was to establish the reliability of arm span as surrogate for height in spine deformity patients whose height might be compromised. Similar results with height and Arm span was recorded by Moneyeki and Sekhotha among rural children in Ellisra, South Africa [9]. Optimal outcomes for spine deformity surgery in pediatric patients are dependent on several factors, which include the nutritional status of the patient, the complexity of the procedure, and other patient comorbidities. At our center, we have established a risk scoring system to predict surgical outcomes and complications. Among the risk factors studied were BMI, ASA, Deformity magnitude, surgical complexity, neurologic status, and diagnosis, all playing critical roles in patient outcomes. We have instituted measures to optimize these risk factors, and therefore optimizing nutritional status means obtaining accurate measures of the BMI value (Fig. 3). The study concentrated on the hypothesis that when there is a deformity in the spine, true height is compromised. The degree of curvature was not considered because of the many variables it introduced during the analysis, such as the location of the curve, magnitude of the curve, angle of measurement, and patients with multiple curves.

The findings from this study suggest that in normal individuals, arm span and height are very similar and therefore BMIs computed with arm span completely reflect Height BMI. Most of the members of the experimental group had various deformities of the spine which had compromised their height and hence the mean height-BMI was higher than their mean arm span-BMI. The result in this study is similar to other investigations reported. For example, Reeves et al. [18] and Kwok and Whitelaw [19] found that arm span can be considered a useful alternative to height, especially in elderly people since arm span does not vary significantly with age. Other studies also found that arm span correlates better with height than do other long bone measurements such as knee height [20]. Height–arm span difference was recorded in both control and case groups, and in both groups, arm span measurement exceeded height as recorded in other studies [14,21]. However, there was a linear relationship with arm span and height BMI in the control group although they were multiethnic (Fig. 1).

Therefore, in circumstances where true height cannot be determined as in the case of individuals with spinal



Admission posture with spine deformity

Post Nutrition and Traction posture

Fig. 3. Pre and post traction & nutrition intervention in an adolescent with severe spine deformity.

deformities, arm span BMIs can be used for assessment instead of the height BMI.

Conclusion

Spine deformity patients can experience significant height losses, which can impact their true BMI values, thereby creating erroneous impressions of their nutritional status. The study showed that arm span can be used as a proxy to height in calculating BMI in pediatric spine deformity patients. Patients with Delta AH $\geqslant$3 cm have a significant negative effect on the BMI calculation. We advise that health workers should consider using the arm span as a substitute to height in BMI calculation and nutritional assessment for spine deformity patients. The recommendation may also hold true for other orthopedic conditions of the lower limbs that grossly affect the height measurements.

References

[1] Weber DR, Leonard MB, Zemel BS. Body composition analysis in the pediatric population. *Pediatr Endocrinol Rev* 2012;10:130–9.

[2] Ibegbu A, Tosin D, Hamman W, et al. Nutritional evaluation using different anthropometric variables in Nigerian school children. *J Exp Clin Anat* 2013;12:42–9.

[3] Lee SY, Gallagher D. Assessment methods in human body composition. *Curr Opin Clin Nutr Metab Care* 2008;11:566–72.

[4] Orden AB, Bucci PJ, Petrone S. Trends in weight, height, BMI and obesity in schoolchildren from Santa Rosa (Argentina), 1990-2005/07. *Ann Hum Biol* 2013;40:348–54.

[5] Sultana T, Karim MN, Ahmed T, et al. Assessment of under nutrition of Bangladeshi adults using anthropometry: can body mass index be replaced by mid-upper-arm-circumference? *PLoS One* 2015;10:e0121456.

[6] Pettersson U, Nordstrom P, Alfredson H, et al. Effect of high impact activity on bone mass and size in adolescent females: a comparative study between two different types of sports. *Calcif Tissue Int* 2000;67:207–14.

[7] Ashwell M, Gibson S. Waist-to-height ratio as an indicator of ‘‘early health risk’’: simpler and more predictive than using a ‘‘matrix’’ based on BMI and waist circumference. *BMJ Open* 2016;6:e010159.

[8] WHO Multicentre Growth Reference Study Group. *WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development*. Geneva: World Health Organization; 2006. Available at: http://www.who.int/childgrowth/standards/technical_report/en/index.html. Accessed December 4, 2017.

[9] Monyeki KD, Sekhotha MM. 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. *Public Health Nutr* 2016;19:1195–9.

[10] Datta Banik S. Arm span as a proxy measure for height and estimation of nutritional status: a study among Dhimals of Darjeeling in West Bengal India. *Ann Hum Biol* 2011;38:728–35.

[11] Karadag B, Ozturk AO, Sener N, et al. Use of knee height for the estimation of stature in elderly Turkish people and their relationship with cardiometabolic risk factors. *Arch Gerontol Geriatr* 2012;54:82–9.

[12] Supare MS, Bagul AS, Pandit SV, et al. Estimation of stature from arm span in medical students of Maharashtra, India. *Ann Med Health Sci Res* 2015;5:218–21.

[13] Quanjer PH, Capderou A, Mazicioglu MM, et al. All-age relationship between arm span and height in different ethnic groups. *Eur Respir J* 2014;44:905–12.

[14] 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.
[15] Mohanty SP, Suresh Babu S, Sreekumaran Nair N. The use of arm span as a predictor of height: a study of South Indian women. *J Orthop Surg* 2001;9:19–23.
[16] Gavriilidou NN, Pihlsgard M, Elmstahl S. High degree of BMI misclassification of malnutrition among Swedish elderly population: age-adjusted height estimation using knee height and demispan. *Eur J Clin Nutr* 2015;69:565–71.
[17] Liu JS, Dong C, Vo AX, et al. Obesity and anthropometry in spina bifida: what is the best measure. *J Spinal Cord Med* 2016:1–8.
[18] Reeves SL, Varakamin C, Henry CJ. The relationship between arm-span measurement and height with special reference to gender and ethnicity. *Eur J Clin Nutr* 1996;50:398–400.
[19] Kwok T, Whitelaw MN. The use of armspan in nutritional assessment of the elderly. *J Am Geriatr Soc* 1991;39:492–6.
[20] Chumlea WC, Guo SS, Wholihan K, et al. Stature prediction equations for elderly non-Hispanic white, non-Hispanic black, and Mexican-American persons developed from NHANES III data. *J Am Diet Assoc* 1998;98:137–42.
[21] Lahner CR, Kassier SM. Veldman. Estimation of true height: a study in population-specific methods among young South African adults. *Public Health Nutr* 2017;20:210–9.