Sitting height ratio and interpretation of BMI-based nutritional status among Sarak adults of Bundu, Ranchi, Jharkhand, India

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Abstract
Sitting height ratio (SHR) affects the rates of nutritional status based on an adjusted body mass index (BMI_{adj}) in adults. Height, weight, and sitting height was measured among 268 adults (158 men) of the Sarak community in Bundu, Ranchi of Jharkhand, India. BMI_{adj} was computed through age-controlled linear regression of SHR on observed BMI (BMI_{ob}) by sex. SHR significantly ($p< 0.05$) predicted BMI_{ob} in either sex. BMI_{ob} (men 20.3 $kg \cdot m^{-2}$; women 19.4 $kg \cdot m^{-2}$) was significantly different ($p < 0.05$) from BMI_{adj} (men 20.5 $kg \cdot m^{-2}$; women 19.7 $kg \cdot m^{-2}$). BMI_{ob}-based rates of undernutrition (men 28%; women 46%) and overweight (men 18%; women 12%) have been estimated. BMI_{adj} marginally underestimated the rates of undernutrition (men 27%; women 44%) and overestimated the prevalence of overweight (men 20%; women 13%). However, concordance of the rates (based on BMI_{ob} and BMI_{adj}), appraised with Kappa statistics was significantly ($p < 0.05$) high (men and women 0.9). Adult Saraks were suffering from high degrees of undernutrition, and the situation of women was worse. The modeling of BMI_{adj} based on SHR needs further verification despite high agreement between BMI_{ob} and BMI_{adj} in evaluating the rates of nutritional status.

KEYWORDS: undernutrition, overweight, observed BMI, adjusted BMI

Introduction
Body mass index (BMI) is a commonly used indicator of overall adiposity. However, BMI is not very useful in distinguishing lean body mass from fat mass (Gallagher et al. 1996: 143). BMI is widely used to estimate rates of nutritional status (undernutrition, overweight, and obesity) in adults (WHO 1995: 854). Sitting height ratio (SHR) is associated with an epidemiological risk for body fatness (Bogin & Varela-Silva 2010: 7). In adults, mean SHR varies in different populations, ranging between 47% and 56% (Eveleth & Tanner 1990). Relatively longer legs or lower SHR was observed among Australian Aborigines (SHR= 47.3% for men and 48.1% for women). In contrast, Guatemala Maya men and Peruvian women had relatively shorter leg length (SHR = 54.6% and 55.8%). African

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adults had longer legs (SHR= 50% to 52%) than Asian adults who had SHR between 51% and 55% (Eveleth & Tanner 1990).

The present study started addressing the question given by Nick Norgan (1994: 21), ‘should BMI cut-off values for chronic energy deficiency (CED) and obesity be adjusted for variations in relative sitting height or RSH (sitting-height/height)?’ The regression analysis of RSH on observed BMI predicted the adjusted BMI that precluded simple adjustment for RSH and recommended additional anthropometric measurements to interpret BMI. Another study carried out among 36 Inuit communities of the Canadian Arctic evaluated the efficacy of RSH adjustment as a method of correcting observed BMI (Galloway et al. 2011). However, in that study, no consistent relationship between RSH and BMI was observed to classify the rates of thinness (undernutrition), overweight and obesity based on observed and corrected BMI.

In this dimension, there was no available report from Indian populations. The objectives of the study among adults included:

1) To compute adjusted BMI through age-controlled linear regression analysis of SHR on observed BMI, by sex.

2) To test the effectiveness of SHR calculating adjusted BMI by comparing rates of nutritional status (undernutrition, normal, and overweight) based on observed and adjusted BMI, by sex.

Methods and participants

The cross-sectional study was carried out in 2007–2009 among adults (age range 18–70 years) of the Sarak community (158 men and 110 women). The location of the study was five villages (Bundu, Manjhituli, Paramdih, Beradih, and Nawadi) of Bundu (an administrative jurisdiction) that was about 45 kilometres from the city of Ranchi, the provincial capital of the state of Jharkhand, India. The participants were selected from the voters’ list (issued by the Election Commission of the Government), without any bias, and the sample represented 83% of male and 81% of female adult Saraks of the studied region.

Anthropometric measurements were recorded following standard protocols (Lohman et al. 1988; WHO 1995: 854). Height and sitting height nearest 0.1 cm and body weight nearest 0.05 kg of the participants were recorded using a standard Martin’s anthropometer and weighing scale (Libra, New Delhi, India), respectively. BMI (expressed in kilograms per square metres) was calculated according to Eq. (1):

$$BMI = \frac{W}{H^2} \tag{1}$$

where W is weight (in kilograms) and H is height (in metres).

BMI cut-off evaluating nutritional status for adult Asian populations was followed (Nishida 2004). SHR as a measure of body proportion was calculated according to Eq. (2) and expressed in percent:

$$SHR = \frac{SH}{H} \times 100 \tag{2}$$

where SH is sitting height (in centimetres) and H is height (in centimetres).

Descriptive statistical tests included mean and standard deviations. Student's *t*-tests were performed to test for sex differences, and one-way analysis of variance (ANOVA) was run to test the age difference in mean anthropometric characteristics. Differences between the proportions of men and women with CED were analysed by the chi-square (χ^2) test (including odds ratio, OR). Linear regression (age-controlled) of SHR on observed BMI (BMI_{ob}) was used to calculate adjusted BMI (BMI_{adj}), following methods described in previous studies (Norgan 1994; Galloway et al. 2011). The formula for BMI_{adj} is defined in Eq. (3). In the formula, $BMI_{0.52}$ was the BMI at an estimated SHR of 0.52.[5] Estimated BMI (BMI_{est}) was another component:

$$BMI_{adj} = BMI_{0.52} + (BMI_{ob} - BMI_{est}). \quad (3)$$

In the model, $BMI_{0.52}$ was according to the Eq. (4):

$$BMI_{0.52} = B_1 * 52 + B_0 \quad (4)$$

where B_1 and B_0 were taken from the sex-specific regression analysis. Estimated BMI (BMI_{est}) was calculated from the regression models for men and women separately. BMI_{est} was according to Eq. (5):

$$BMI_{est} = B_1 * (\text{individual SHR}) + B_0 \quad (5)$$

where B_1 represented the β coefficient and B_0 represented the intercept of the regression of SHR on BMI_{ob} in the models.

In the regression model, the R^2 coefficient of determination estimates the relative amount of variance of the dependent variable explained by the explanatory variables. Adjusted R^2 adjusts for the number of explanatory terms in a model. The prevalence of undernutrition (thinness), normal weight, and overweight based on BMI_{ob} and BMI_{adj} were compared using the Cohen's Kappa statistic (Viera & Garrett 2005). Statistical Package for Social Sciences version 13 (SPSS 2004 edition, Chicago, Illinois, USA) was used for the analysis and statistical significance was set at $p < 0.05$. Ethical approval was obtained from appropriate authorities before the commencement of the study. Informed consent was also obtained from local community leaders and each participant.

Results and discussion

The mean age did not vary significantly by sex. Higher mean values were observed among men for height, weight, sitting height, BMI_{ob}, and BMI_{adj} compared to women with significant sex difference ($p < 0.05$) (Table 1). No significant age difference (tested by ANOVA) was observed in either sex except for sitting height with lower mean in higher age groups of men and women (18–39 years, 40–59 years, and 60–70 years). Sitting height had mean values in three age-groups with significant age differences in: men (18–39 years = 82.2 cm; 40–59 years = 80.8 cm; 60–70 years = 79.9 cm; ANOVA, F statistic = 5.3, $p < 0.05$) and women (18–39 years = 75.7 cm; 40–59 years = 74.8 cm; 60–70 years = 72.5 cm; F = 7.1, $p < 0.05$).

Table 1: Characteristics of the sample of adult Saraks of Bundu, Ranchi

Variables	Mean ± SD		t
	Men	Women	
Age [years]	42.9 ± 15.4	44.5 ± 16.1	-0.7
Height [cm]	161.5 ± 6.2	147.4 ± 6.5	17.9*
Body weight [kg]	53.0 ± 9.2	42.20 ± 8.2	9.9*
Sitting height [cm]	81.3 ± 3.8	74.7 ± 3.4	14.6*
BMIob [kg·m-2]	20.3 ± 3.0	19.4 ± 3.5	2.2*
BMIadj (kg·m-2]	20.5 ± 3.0	19.7 ± 3.4	2.1*
SHR (%)	50.4 ± 1.9	50.7 ± 2.2	-1.3

Men = 158; Women = 110; SD: Standard deviations; BMIob j= Observed body mass index; BMIadj = Adjeusted body mass index; SHR= Sitting height ratio. t = t-statistic of Student's t-test; * p < 0.05

Linear regression model of predicting BMI_{ob} from SHR after controlling age was significant as tested by ANOVA ($p < 0.05$). BMI_{ob} and SHR had significant linear relationships. Among men regression coefficient (B_0) indicated that a 1% increase in SHR caused a 0.5 $kg \cdot m^{-2}$ decrease in BMI_{ob}. Among women, a 1% increase in SHR caused a 0.6 $kg \cdot m^{-2}$ decrease in BMI_{ob}. F-change was also significant ($p < 0.05$) in the models of either sex. Regression models explained 8% and 16% of the variation in the BMI_{ob} for men and women respectively. R^2 and adjusted R^2 values were very close anticipating minimal shrinkage based on SHR in the models (Table 2).

Table 2: Linear regression analysis (age-adjusted) of SHR on BMI in adult Saraks of Bundu, Ranchi

Sex		B	SE	Beta	t	R2	Adj R2	F change
Men	Constant	-2.8	6.3		-0.5	-	-	-
	SHR [%]	0.5	0.1	0.3	3.6*	0.1	0.1	12.9*
Women	Constant	-11.4	7.2		-1.6			
	SHR [%]	0.6	0.1	0.4	4.4*	0.2	0.2	19.7*

B = Unstandardized coefficient; SE = Standard error; Beta = Standardized coefficient; SHR = Sitting height ratio; R2 = coefficient of determination; AdjR2 = Adjusted R square; * p < 0.05

The nutritional status evaluated by BMI_{ob} and BMI_{adj} (Eq. 3) exhibited a remarkably high rate of undernutrition in men and women of the Sarak community. Women had high prevalence of thinness (BMI < 18.5 $kg \cdot m^{-2}$) based on either BMI_{ob} (46.4%) or BMI_{adj} (43.6%). In contrast, men had a relatively lower rate of undernutrition compared to women, based on either BMI_{ob} (27.9%) or BMI_{adj} (27.2%). At the same time, the frequency of overweight (BMI ≥ 23 $kg \cdot m^{-2}$) in men and women was also high. In this regard, the rate estimated by BMI_{adj} was slightly higher than that estimated by BMI_{ob}. The difference between men and women for underweight or others (normal and overweight) was significant (BMI_{ob} $\chi^2 = 7.0$, $p < 0.05$; BMI_{adj} $\chi^2 = 6.3$; $p < 0.05$). The Odds Ratio

(OR) for BMI_{ob} was 2.6 ($p < 0.05$) and for BMI_{adj} was 2.1 ($p < 0.05$). This result implied that among adult Saraks, women had at least more than a two-fold greater chance of being chronically energy deficient, diagnosed either by BMI_{ob} or BMI_{adj}. Cohen's Kappa coefficient evidenced significant agreement between the classifications of the rates of nutritional status based on BMI_{ob} and BMI_{adj} in men (0.9) and women (0.9) (Table 3).

Table 3: Rates of nutritional status estimated by BMIob and BMIadj in adult Saraks of Bundu, Ranchi

Nutritional status	Men		Women	
	BMIob [kg·m-2]	BMIadj [kg·m-2]	BMIob [kg·m-2]	BMIadj [kg·m-2]
Undernutrition [%]	27.9	27.3	46.4	43.6
Normal [%]	53.8	53.2	41.8	43.6
Overweight [%]	18.4	19.6	11.8	12.7

Men = 158; Women = 110; BMIob: Observed body mass index; BMIadj: Adjusted body mass index

Remarkable rates of undernutrition were also recorded among adults of some communities of eastern India. In the state of West Bengal, reports are available from Telegas of Kharagpur (men 25.5%, women 29.1%) (Datta Banik 2007: 31) and three populations of the Darjeeling District: Dhimal (men 27.0%, women 46.4%) (Datta Banik et al. 2007: 28), Mech (men 9.9%, women 16.9%), and Rajbanshi (men 17.3%, women 29.3%) (Datta Banik et al. 2009b). Previous studies done by the author in two communities of Ranchi district in Jharkhand state included: Oraon (men 53.1%, women 62.5%) and the present sample of the Sarak community (men 27.8%, women 46.4%) (Datta Banik 2011: 50; Datta Banik et al. 2009a: 47). In all studies, the prevalence of CED was found to be higher among women.

The present study displayed that BMI_{adj} underestimated thinness and overestimated overweight among Sarak men and women in comparison to BMI_{ob} though the differences were marginal. However, in the earlier study among adult Inuit Canadians, differential rates estimated by BMI_{ob} and BMI_{adj} for underweight in men (BMI_{ob} 0.4%, BMI_{adj} 0.8%) and women (BMI_{ob} 1.4%, BMI_{adj} 2.3%) and overweight or pre-obese in men (BMI_{ob} 33.9%, BMI_{adj} 33.9%) and women (BMI_{ob} 24.8%, BMI_{adj} 24.9%) exhibited equal or overestimation by BMI_{adj} (Galloway et al. 2011: 23). In that study, despite inconsistencies in the evaluation of nutritional status by BMI_{ob} and BMI_{adj}, overall concordance was recorded (Cohen's Kappa statistic = 0.7, $p < 0.001$). The present study has shown similar agreement between BMI_{ob} and BMI_{adj} and conformed to the earlier study.

Conclusion

In this study, the adjustment of BMI using SHR has demonstrated a significant linear relationship between these two anthropometric indicators. $BMI_{0.52}$ was taken from the previous study, which was based on an entirely different population (Norgan 1994). SHR value representing Indian populations might be more useful in calculating $BMI_{0.52}$ and accordingly BMI_{adj}. The inconsistencies in evaluating nutritional status in adults by BMI_{ob} and BMI_{adj}, despite the overall agreement, need further verifications.

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Povzetek

Razmerje med sedečo višino in višino vpliva na razvrščanje v skupine prehranjenosti, ki temelji na prilagojenem indeksu telesne mase pri odraslih. Višino, maso in sedno višino smo izmerili pri 268 odraslih (158 moških) v skupnosti Sarak v Bundu, Ranchi, Jharkhand, Indija. Prilagojeni indeks telesne mase je bil izračunan s pomočjo linearne regresije razmerja med sedečo višino in višino na opazovanem indeksu telesne mase, ločeno po spolu ob nadzoru starosti. Razmerje med sedečo višino in višino statistično značilno ($p < 0,05$) napoveduje indeks telesne mase obeh spolov. Indeks telesne mase (moški 20,3 kg·m-2, ženske 19,4 kg·m-2), je bistveno drugačen ($p < 0,05$) od prilagojenega indeksa telesne mase (moški 20,5 kg·m-2, ženske 19,7 kg·m-2). Ocenili smo deleže podhranjenosti, ki temeljijo na indeksu telesne mase (moški 28%, ženske 46%) in tudi deleže prekomerne hranjenosti (moški 18%, ženske 12%). Prilagojeni indeks telesne mase nekoliko podcenjuje delež podhranjenosti (moški 27%, ženske 44%) in precenjuje delež prekomerno prehranjenih (moški 20%, ženske 13%). Kljub temu je bila skladnost stopenj (na podlagi indeksa telesne mase in prilagojenega indeksa telesne mase), ocenjene s statistiko Kappa, statistično značilna ($p < 0,05$) in visoka (moški in ženske 0,9). Odrasli Saraki kažejo visoke deleže podhranjenih, še posebej med ženskami. Modeliranje prilagojenega indeksa telesne mase za ocenjevanje stopnje hranjenosti, ki temelji na razmerju med sedečo višino in višino, je potrebno še naprej preverjati kljub visoki skladnosti med indeksom telesne mase in prilagojenim indeksom telesne mase.

KLJUČNE BESEDE: podhranjenost, prekomerna telesna masa, indeks telesne mase, prilagojeni indeks telesne mase

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