



GROWTH AND MATURATION IN HUMAN BIOLOGY AND SPORTS

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BY FELLOWS AND COLLEAGUES*

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STATURE–OBESITY RELATIONSHIPS AMONG 11,000 SCHOOL-AGED AMERICAN INDIAN CHILDREN

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Big children are most often tall as well as heavy. Stovitz and colleagues (2008) have demonstrated that the tallest U.S. children also have the highest current body mass index (BMI), and that they are more likely than their shorter peers to become overweight or obese as young adults (Stovitz *et al.*, 2010). American Indian children are among the tallest children in the world (Haas & Campirano, 2006; Eveleth & Tanner, 1990), and they have among the highest prevalences of overweight and obesity compared with other children in the United States and elsewhere (Zephier *et al.*, 2006). Nevertheless, there is no information about the relationships between stature and obesity in American Indian children. Because of the elevated risks of obesity and its sequelae in childhood and adulthood, understanding the relationships between growth in stature and excess weight is important for evaluating the growth of American Indian children and for clinical management. Herein, we investigate relationships between stature, BMI and obesity for a large sample of American Indian children, 5-18 years of age, residing on 12 reservations in the Northern Plains of the United States.

MATERIALS AND METHODS

The sample children attended 55 schools where at least 50% of children enrolled were American Indians, and that were located on or adjacent to 12 reservations. The reservations comprise the Aberdeen Area of the Indian Health Service (IHS) and include tribes in the states of Iowa, South Dakota, North Dakota and Nebraska. A single well-trained measurement team of 7 individuals collected all data on gender, age, stature and weight during the 2002-2003 school year. For height and weight standardized measurement protocols and equipment were used (Lohman *et al.*, 1988). Data are only reported for American Indian children.

Improbable values for stature and weight were excluded, as were data for children beyond the age cut-offs, leaving a sample of 11,099 children (5661 boys) 5.00-18.99 years of age with complete data. For some analyses children were grouped into whole-year age groups (e.g., 5 yrs = 5.00-5.99 yr). BMI was calculated as weight (kg)/stature (m)². Exact percentiles and z-scores for stature, weight and BMI were calculated relative to the CDC 2000 Growth Charts (Kuczmarski *et al.*, 2000). Z-scores or standard deviation scores express the measurements in terms of standard deviation units above or below the reference means for that gender and age, so that a z-score of zero

corresponds to exactly the reference mean. Overweight was considered as BMI \geq 85th percentile, and obesity BMI \geq 95th percentile following national recommendations (Krebs *et al.*, 2007). Unconditional logistic regression was used to estimate adjusted odds ratios (OR) of variables contributing to overweight and obesity status.

Informed parental consent was obtained according to individual school policies. In some schools, measurements were incorporated into regular health-screening activities. All procedures were approved by the appropriate institutional review boards for tribes and the IHS.

RESULTS

Table 1 presents previously unpublished mean stature and BMI for each gender in whole-year age groups. The means demonstrate the expected patterns of growth in stature and BMI across this age range.

Table 1. Means and standard deviations for stature and BMI of American Indian children

Age (y)	Boys					Girls				
	N	Stature (cm)		BMI (kg/m ²)		N	Stature (cm)		BMI (kg/m ²)	
		Mean	SD	Mean	SD		Mean	SD	Mean	SD
5	310	115.9	5.3	17.7	3.3	321	115.1	5.4	17.5	3.0
6	489	121.4	5.6	18.0	3.7	459	120.1	5.6	17.7	3.2
7	511	127.4	6.2	18.5	4.0	484	126.8	5.8	18.4	3.4
8	507	133.3	6.0	19.4	4.4	483	131.9	6.3	19.4	4.0
9	585	138.4	6.7	20.4	4.9	529	138.7	6.5	20.3	4.3
10	573	143.5	7.1	21.6	4.9	542	144.0	7.5	21.1	5.1
11	533	150.0	7.7	22.9	6.0	536	150.7	7.3	22.5	5.3
12	518	156.2	8.3	23.6	6.0	479	156.2	7.1	23.2	5.3
13	460	162.0	8.1	23.9	5.9	488	160.1	6.3	24.0	5.9
14	381	168.2	8.1	24.3	6.2	396	162.1	6.4	24.6	5.7
15	285	172.6	7.6	24.5	6.1	270	162.9	6.2	25.4	5.9
16	216	174.9	7.6	25.4	7.0	222	164.0	6.1	25.4	5.5
17	203	176.0	6.9	25.6	6.4	148	163.8	6.7	26.1	6.7
18	90	178.2	7.3	25.9	6.0	81	164.2	5.6	26.6	5.8

The age-related patterns of growth in stature and BMI can be better appreciated when presented as z-scores relative to US national data (**Figure 1**). These children clearly have elevated mean z-scores for stature and BMI at every age relative to national data, with mean BMI z-scores substantially higher than stature z-scores. For stature in both genders and for BMI in boys there is a general trend of decreasing mean z-scores across these ages. The short-term marked rises in mean stature z-scores at about 10 years in boys and 9

years in girls probably represent relatively advanced maturational timing of the events surrounding adolescence in these children relative to the national reference.

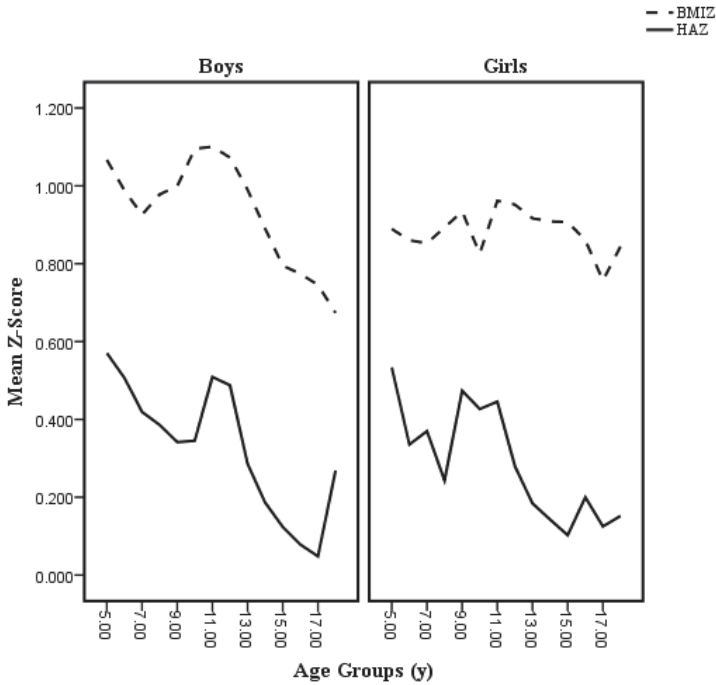


Figure 1: Mean z-scores for BMI and stature in boys and girls by whole-year age groups

The age-related patterns of prevalences of overweight and obesity are presented for boys and girls in **Figure 2**. Prevalences of overweight and obesity are very high in every age group. For boys prevalences peak at 11 years at 57.2% and 37.0% for overweight and obesity, respectively. In girls prevalence of overweight peaks at 51.8% at 12 years, and for obesity at 29.9% in the 11-year age group.

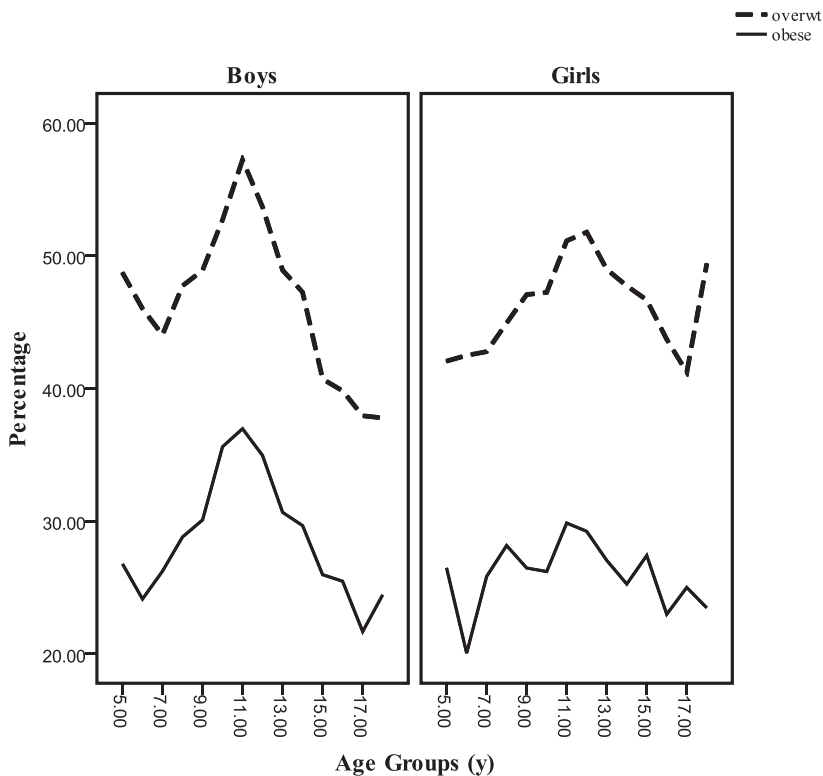


Figure 2: Prevalences of overweight and obesity by whole-year age groups

In these children correlations between stature z-scores and BMI z-scores are $r=0.38$ for boys and $r=0.31$ for girls. The corollary of this substantial positive relationship between stature and BMI can be seen in **Figure 3** which presents median BMI z-scores, plotted for integer categories of stature z-scores. Clearly, taller children have greater BMI, and even for the shortest children, median BMI exceeds zero.

Finally, the results of logistic models investigating determinants of overweight and obesity status based on BMI are presented in **Table 2**. This analysis translates the associations between BMI and stature into adjusted odds ratios quantifying the risks of overweight and obesity according to categories of stature. Boys are about 15% more likely than girls to be obese (OR=1.16), controlling for stature and age, but a similar gender difference does not occur for overweight. There is an increase in adjusted prevalences of overweight and obesity of approximately 2% per year of age, controlling for gender and stature.

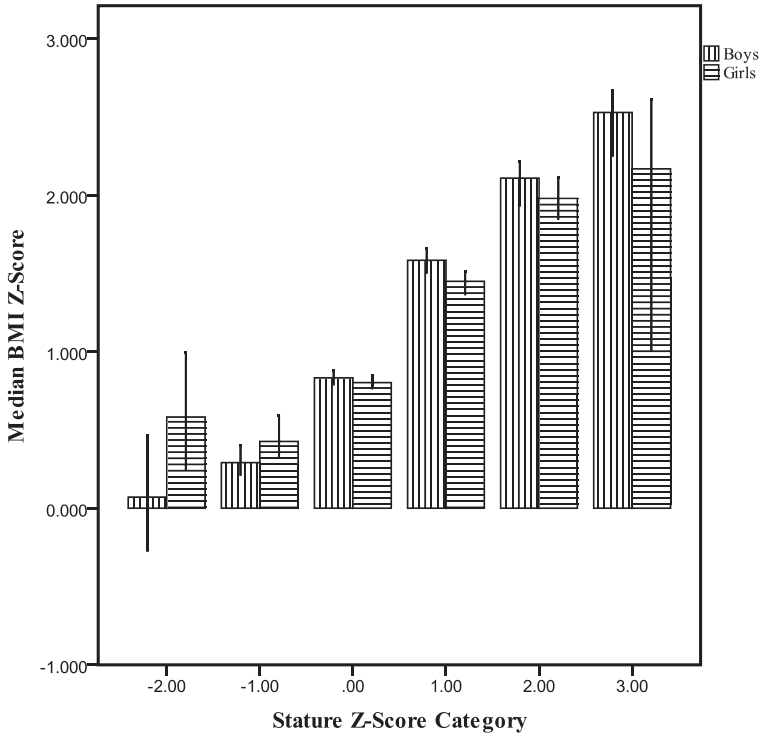


Figure 3: Median BMI Z-Scores (\pm 95% CI) by integer stature z-score categories

Integer categories of stature z-scores provide dramatic independent associations with prevalences of overweight and obesity. Compared with the shortest children, those whose stature is close to the median (z-score category '0') are still significantly more likely to be overweight (OR=1.68), and risks increase with each subsequently higher stature z-score category, such that children in the highest z-score category (+3.0) have more than 11

times the risk of being overweight. Consecutively higher odds ratios relative to shortest peers are observed for obesity status beginning at stature z-score categories of +1, +2, and +3, where adjusted odds ratios are 3.9, 9.4, and 15.5, respectively.

Table 2: Results from logistic models for overweight and obesity status

Variable	Overweight			Obesity		
	OR	95% CI	Sig.	OR	95% CI	Sig.
Gender (boys)	1.05	0.97, 1.13	0.266	1.16	1.06, 1.26	0.001
Age (yr)	1.02	1.00, 1.03	0.007	1.03	1.01, 1.04	<0.001
Stat -2 Z	Reference	-	-	Reference	-	-
Stat -1 Z	0.83	0.56, 1.23	0.355	0.57	0.35, 0.92	.022
Stat 0 Z	1.68	1.17, 2.41	0.005	1.37	0.89, 2.13	.154
Stat +1 Z	4.34	2.99, 6.29	<0.001	3.90	2.51, 6.07	<0.001
Stat +2 Z	8.77	5.74, 13.40	<0.001	9.43	5.87, 15.16	<0.001
Stat +3 Z	11.50	5.61, 23.59	<0.001	15.48	7.70, 31.12	<0.001

DISCUSSION

Our analyses showed that American Indian school children from the Northern Plains are clearly tall and have high BMI relative to national reference data. In a comparative study of children from around the world, including the current sample, Haas and Campirano (2006) found American Indian youth to be among the very tallest. Historically, American Indians of the Northern Plains were considered tall as children and adults (Wissler, 1911; Sullivan 1920). An implication of these earlier studies was that the tallness was due primarily to genetic factors. Clearly, nowadays the tallness is associated with overweight and obesity. This finding does not necessarily mean that the tall stature is unrelated to genetic factors, nor that the tallness necessarily results from large gains in BMI or from overweight or obesity status. Because the current data are cross-sectional no conclusions about causality or the direction of causality in the associations between stature and obesity can be made. For example, it may be that the same genes that favor tallness also favor weight gain in an obesogenic environment. Longitudinal study is required to help understand temporal associations between growth in stature and BMI.

The current data are consistent with results in other children indicating positive associations between stature and BMI, and stature and fatness during childhood (Himes and Roche, 1986; Freedman *et al.*, 2004; Stovitz *et al.*, 2008), although these associations

do not persist in adults. Distinguishing between stature associations with BMI and stature associations with fatness is important because, although BMI is often used as a surrogate for body fatness and obesity status, BMI is really only a measure of body mass and not body fatness *per se*. Also, BMI includes stature in its denominator, and the squared term for stature may not be the exact exponential to best standardize weight at some ages in childhood, yielding residual associations with stature as an artifact of the formula used (Cole, 1991).

Some of the tallness of American Indian children in our sample is probably due to relatively advanced somatic maturation or growth tempo. As boys approach adolescence they accumulate weight and body fat about two years before they undergo the adolescent spurt in stature (Malina & Bouchard, 1991). The rises in z-scores for stature and BMI relative to the reference data at 9 and 10 years of age (**Figure 1**) almost certainly reflect entrance into these periadolescent events earlier than the national data so that the z-scores rise abruptly. The same pattern is seen for mean stature z-scores in girls. Most of the relative population stature advantage is lost in the oldest age groups, where the American Indian children are only slightly taller as young adults than the national norms. This is the expected pattern if the tallness were due to relatively advanced somatic maturation. Unfortunately, we are not aware of any contemporary data available for American Indians concerning the timing of adolescent events such as secondary sex characteristics or menarche that could conclusively confirm this finding.

It is tempting to view those children considered overweight and obese during the puberty-related increases in prevalences (**Figure 2**) as misclassified because they are simply early maturing children relative to national averages. Nevertheless, some recent analyses indicate that at the high levels of BMI cut-offs defining overweight and obesity the actual effects of the relative timing of somatic maturation on obesity misclassification is very small, probably clinically unimportant, and typically less than 1 BMI unit (Himes *et al.*, 2009).

Although the biological etiology of the stature-BMI association may be unclear, it is clear that a strong positive association exists. Longitudinal analyses in other children indicate that such tallness-for-age in childhood is predictive of increased likelihood of being overweight or obese as young adults (Stovitz *et al.*, 2010). The high prevalence of overweight and obesity in American Indian adults is well established, as are high burdens of obesity-related sequelae such as type 2 diabetes mellitus and cardiovascular disease (Story *et al.*, 2003; Compher, 2006).

During the childhood years the BMI associations with stature are sufficient that even children approximately one standard deviation taller than the national average ($\approx 85^{\text{th}}$ percentile) have a four-fold risk of being overweight or obese compared to the shortest children. At the highest levels of stature-for-age the odds ratio for risk for overweight is 11.5 and 15.5 for obesity. These dramatic associations should alert health professionals of the current and future risks for tall American Indian children. The clinical notion held by

some that tall children will outgrow their overweight or obesity is just not supported by the evidence.

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