The effect of ethnicity on appendicular bone mass in white, coloured and Indian schoolchildren

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Abstract **Ethnic differences in the incidence and prevalence of osteoporosis have been shown throughout the world. In South Africa the prevalence of osteoporosis is much higher in whites than in blacks. This is surprising, since factors that might predispose to reduce bone mass are more preponderant in black communities. The present research was undertaken to determine whether differences in bone mass during the period of bone accretion could explain the difference in the incidence of osteoporosis. In this paper we report on differences in appendicular bone mass between white, coloured and Indian children and teenagers (6 - 18 years) from Johannesburg. The effects of weight, height, puberty and skinfold thickness on bone mass were also assessed. The bone width (BW) of white boys was greater than that of Indian boys, while the bone mineral content (BMC) and BMC/BW were greater in white boys than in both Indian and coloured boys. After adjustment for differences in weight and height, the BW of coloured boys was significantly greater than that of white boys, while all differences in BMC and BMC/BW became non-significant. For girls there were no significant differences in bone mass measurements, but after adjustment for height and weight coloured girls had significantly greater BMC and BMC/BW than either white or Indian girls. This greater weight- and height-adjusted bone mass in coloured girls is consistent with the impression of a lower incidence of osteoporosis in coloured women than in white women.**

S Afr Med J 1993; **83**: 847-853.

South African black women have a paradoxically lower incidence of osteoporosis than white women.[1,2] This is so despite generally lower consumption of calcium-containing foods, higher gravidity and longer periods of lactation (factors considered to lower bone mass) in black communities.

Similar ethnic differences in the incidence and prevalence of osteoporosis have been reported elsewhere.[3-8]

Evidence from the USA suggests that ethnic differences in the incidence of osteoporosis can partially be accounted for by differences in the peak bone mass of early adulthood, blacks having a higher peak bone mass than whites.[9-14] Factors that might contribute to differences in peak bone mass have not been elucidated, however, and it is not clear when these differences in bone mass may emerge.

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Accepted 22 Jan 1993.

The present study was undertaken to compare bone mass during the period of bone growth (6 - 18 years) between four racial groups in South Africa. Factors that putatively influence bone mass, namely height, weight, body fat and puberty, were also examined. We have previously reported on differences between blacks and whites.[15] Here we present data comparing coloured, Indian and white children and teenagers.

Subjects and methods

A total of 808 schoolchildren, aged between 6 and 18 years, from private (white children) and government (coloured and Indian children) schools in the suburbs of Johannesburg were studied. The sample, randomly selected from children from whom consent was obtained, was stratified equally according to ethnicity, sex and age. Each age group of 1 year (e.g. 6-year-old white girls) comprised between 8 and 12 subjects.

Appendicular bone mass was measured at the distal third of the right radius using the Norland Cameron single-photon absorptiometer (model 278A). Weight was measured on an electronic scale (Soehnle Digital S770000), and height with a portable stadiometer. Skinfold thickness was measured with Harpenden calipers at the right biceps, triceps, subscapular and supra-iliac sites. The sum of the skinfold thickness was log-transformed when assessing the effect of body fat on bone mass. Pubertal development was assessed in children over the age of 10 years by the Tanner method.[16,17]

SAS statistical procedures were used to analyse and compare data. Height, weight, age, bone width (BW), bone mineral content (BMC) and BMC/BW were compared between ethnic groups of each sex and between boys and girls of each ethnic group by analysis of variance. Bone mass measurements between the ethnic groups were further analysed by analysis of covariance, with height and weight as covariates. Puberty was analysed by probit analysis.

Multiple regression analysis was used to assess the effect of the independent variables weight, height log of skinfold-thickness, testicular volume and the time since the onset of menarche on the dependent variables BW, BMC and BMC/BW.

The effects of puberty on bone mass were also assessed by calculating the regression equation for BW, BMC and BMC/BW in prepubertal children. The equations thus obtained were used to predict bone measurements in pubertal and post-pubertal children. The differences between predicted and observed bone mass measurements in pubertal children, determined by the paired *t*-test, were assumed to be due to the effects of puberty. The study was approved by the Committee for Research on Human Subjects of the University of the Witwatersrand. Written consent was obtained from parents and guardians and verbal consent was obtained from the subjects at the time of the study.

Results

Weight and height (Fig. 1)

Weight and height were compared with the NCHS per-

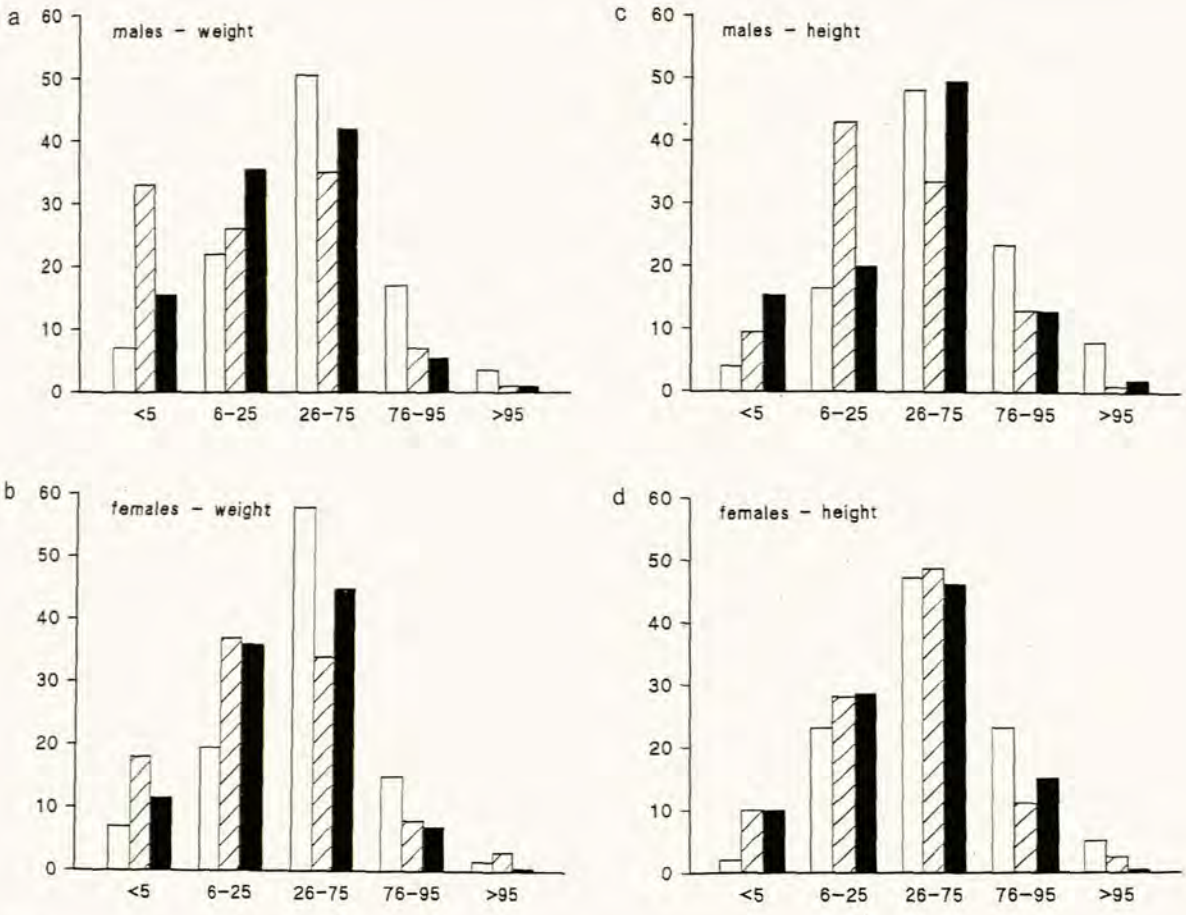

FIG. 1.
Percentage of children falling within the various NCHS percentiles for: (a) males — weight for age; (b) females — weight for age; (c) males — height for age; and (d) females — *height for age* (□ = whites; ▨ = Indian; ■ = coloured).

centile standards[18] (Fig. 1). White boys (weight 44,6 ± 18,3 kg; height 152,9 ± 21,7 cm (mean ± SD)) were significantly ($P < 0,0167$) heavier and taller than Indian (weight 37,1 ± 14,4 kg; height 147,4 ± 19,0 cm) and coloured (weight 38,3 ± 15,6 kg; height 146,3 ± 19,5 cm) boys, but coloured and Indian boys did not differ from each other.

White girls (weight 42,2 ± 13,8 kg; height 149,4 ± 16,5 cm) were also significantly ($P < 0,0167$) heavier and taller than Indian (weight 37,7 ± 13,5 kg; height 145,2 ± 15,4 cm) and coloured (weight 37,3 ± 13,7 kg; height 144,3 ± 17,4 cm) girls, and again the latter two groups did not differ from each other.

Puberty

There were no significant differences between the ethnic groups in mean ages of onset of the different stages of puberty. The mean (± SD) ages at onset of pubic hair development and genital development for white boys were 12,6 ± 1,2 years and 11,3 ± 1,5 years, respectively, while for Indian boys they were 10,3 ± 0,7 years and 11,1 ± 0,99 years and for coloured boys 12,0 ± 2,4 years and 10,1 ± 1,16 years, respectively. Testicular volume was also similar in the three groups with a mean of 13,8 ± 9,7 ml for white boys, 13,5 ± 8,1 ml for Indian boys and 14,0 ± 9,3 ml for coloured boys.

The mean ages of onset of pubic hair development, breast development and menarche for white girls were 11,2 ± 0,8 years, 11,2 ± 1,1 years and 13,0 ± 0,9 years, respectively, while for Indian girls they were 11,3 ± 1,2 years, 10,8 ± 1,3 years and 12,9 ± 1,29 years and for coloured girls 11,5 ± 0,9 years, 10,8 ± 1,2 years and 13,0 ± 1,32 years, respectively.

Bone mass

Factors influencing bone mass

The effects of weight, height, log of the sum of skinfold thickness, and time since the onset of menarche in girls and testicular volume in boys on the bone mass variables were analysed by regression analysis (Table I). Only those subsets in which each of the independent variables were significantly related to the dependent variable, in which the coefficient of determination (R^2*100%) for each model was maximum or close to maximum and in which the Mallows' C(p) statistic[19] for each model selected was the smallest or close to the smallest, were selected.

There was a high degree of correlation between the independent variables and also between the independent and the dependent variables (Table II). This introduced a problem of multi-colinearity which made the interpretation of the independent effects of these regressors on the bone mass measurements difficult.

Weight was a consistent predictor of all the bone mass measurements in all groups, except for BMC/BW in Indian girls. Height was a significant ($P < 0,05$) regressor of BMC/BW for both boys and girls (except for BMC/BW in coloured boys). It was also a significant regressor for BMC in girls, but not in boys. For white and coloured boys and Indian girls it was a significant predictor of BW as well.

Skinfold thickness does not have a Gaussian distribution in the population; the sum of the values of skinfold thickness was therefore log-transformed, and this was used in the regression equation as a measure of body fat. It was negatively correlated to BW and BMC in both boys and girls of all groups and to BMC/BW in white

TABLE I.
Regression analysis of factors influencing bone mass measurements

	R^2*100%
Males	
Whites	
BW = weight + height – SFT	82
BMC = weight + testvol. – SFT	90
BMC/BW = weight + height + testvol. – SFT	80
Coloured	
BW = weight + height – SFT	76
BMC = weight + testvol. – SFT	87
BMC/BW = weight + testvol. – SFT	89
Indian	
BW = weight + testvol. – SFT	73
BMC = weight + testvol. – SFT	86
BMC/BW = weight + height + testvol.	71
Females	
White	
BW = weight – SFT	56
BMC = weight + height + mendur. – SFT	90
BMC/BW = weight + height + mendur.	79
Coloured	
BW = weight – SFT	60
BMC = weight + height + mendur. – SFT	89
BMC/BW = weight + height + mendur.	76
Indian	
BW = weight + height – SFT	64
BMC = weight + height + mendur. – SFT	85
BMC/BW = height + mendur. + SFT	62

Variables included in the regression analysis were weight (kg), height (m), log sum of skinfold thickness (SFT), testicular volume (testvol.)(ml), and time since onset of menarche (mendur.) (years). Only variables that significantly influenced the regression analysis are included. The intercept and parameter estimates have been left out for simplicity.

and coloured boys after the inclusion of weight in the equation. It was positively correlated to BMC/BW in Indian girls when height but not weight was included in the equation.

Testicular volume was a significant predictor of BMC and BMC/BW in all boys. It did not contribute to explaining the variation in BW, except in Indian boys. For females the duration of menstruation was a significant predictor of BMC and BMC/BW, but it was not correlated to BW in any of the ethnic groups. Table III shows the comparisons observed with predicted bone mass measurements in pubertal children. The observed bone width of boys and girls was significantly lower than the predicted BW; however, observed BMC and observed BMC/BW were significantly greater than predicted by the equation for both girls and boys.

TABLE III.
Effects of puberty on bone mass

	Observed	Predicted	*P*-value
BW			
Boys	1,2661	1,3074	0,0001
Girls	1,1427	1,1883	0,0001
BMC			
Boys	0,8072	0,7600	0,0001
Girls	0,7221	0,6117	0,0001
BMC/BW			
Boys	0,6280	0,5982	0,0001
Girls	0,248	0,5617	0,0001

Comparisons between the means of predicted v. observed bone mass variables in pubertal and post-pubertal children.

Gender differences in bone mass

Gender comparisons of bone mass measurements were made within each ethnic group (Table IV). BW and BMC were significantly greater in boys than in girls (except for BMC in Indian children). BMC normalised for BW did not differ significantly between girls and boys, however.

When the effects of height and weight were taken into account, adjusted BW and adjusted BMC remained significantly greater in boys than in girls. BMC/BW also remained significantly greater in white boys than in white girls, but there were no significant differences in BMC/BW between 'coloured' and Indian boys and girls.

Ethnic differences in bone mass

BW. The BW of white boys was significantly greater than that of Indian boys (Table IV, Fig. 2a) After adjus-

TABLE II.
Correlation coefficients (*r*) of dependent and independent variables used in the regression equation

	Weight	Height	SFT	Testvol.	BW	BMC	BMC/BW
Weight							
r	1,0000	0,9216	0,4907	0,8575	0,8489	0,9099	0,8310
P-value	0,0	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
Height							
r	0,9216	1,0000	0,2875	0,8782	0,8482	0,8943	0,8303
P-value	0,0001	0,0000	0,0001	0,0001	0,0001	0,0001	0,0001
SFT							
r	0,4907	0,2875	1,0000	0,1689	0,2383	0,2577	0,2486
P-value	0,0001	0,0001	0,0000	0,0004	0,0001	0,0001	0,0001
Testvol.							
r	0,8575	0,8782	0,1689	1,0000	0,7969	0,8756	0,8162
P-value	0,0001	0,0001	0,0004	0,0000	0,0001	0,0001	0,0001
BW							
r	0,8489	0,8482	0,2383	0,7969	1,0000	0,9076	0,7056
P-value	0,0001	0,0001	0,0001	0,0001	0,0000	0,0001	0,0001
BMC							
r	0,9099	0,8943	0,2577	0,8756	0,9076	1,0000	0,9249
P-value	0,0001	0,0001	0,0001	0,0001	0,0001	0,0000	0,0001
BMC/BW							
r	0,8310	0,8303	0,2486	0,8162	0,7056	0,9249	1,0000
P-value	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0000

SFT = skinfold thickness; testvol. = testicular volume.

TABLE IV.
Comparisons of means and least-square means (corrected for height and weight) of bone mass measurements between ethnic groups and between the sexes (within each ethnic group)

	White	Coloured	Indian	Comparison	*P*-value (ANOVA)	*P*-value (CANOVA)
BW				WM v. CM	NS	*
Analysis of variance (means)				WM v. IM	*	NS
Males	1,1982	1,1586	1,1398	CM v. IM	NS	NS
Females	1,0892	1,0604	1,0604	WF v. CF	NS	NS
				WF v. IF	NS	NS
Analysis of covariance (ls means)			CF v. IF	NS	NS	
Males	1,1519	1,18	1,1634	WM v. WF	*	*
Females	1,0633	1,0747	1,068	CM v. CF	*	*
				IM v. IF	*	*
BMC				WM v. CM	*	NS
Analysis of variance (means)				WM v. IM	*	NS
Males	0,7432	0,6662	0,6595	CM v. IM	NS	NS
Females	0,6455	0,6192	0,6033	WF v. CF	NS	NS
				WF v. IF	NS	NS
Analysis of covariance (ls means)			CF v. IF	NS	*	
Males	0,6844	0,6919	0,6909	WM v. WF	*	*
Females	0,6106	0,6372	0,6151	CM v. CF	*	*
				IM v. IF	NS	*
BMC/BW				WM v. CM	*	NS
Analysis of variance (means)				WM v. IM	*	NS
Males	0,6018	0,5657	0,5645	CM v. IM	NS	NS
Females	0,583	0,5693	0,5595	WF v. CF	NS	*
				WF v. IF	NS	NS
Analysis of covariance (ls means)			CF v. IF	NS	*	
Males	0,5774	0,5758	0,5781	WM v. WF	NS	*
Females	0,5649	0,579	0,5653	CM v. CF	NS	NS
				IM v. IF	NS	NS

* Significant difference after Bonferroni adjustment.
ls = least-square; W = white; C = coloured; I = Indian; M = males; F = females; NS = not statistically significant.

ting for height and weight the difference was no longer significant, but coloured boys had a significantly greater height- and weight-adjusted BW than white boys. There were no significant differences in BW between the ethnic groups among girls (Table IV, Fig. 2b).

BMC. The BMC of white boys was significantly greater than that for either coloured or Indian boys (Table V, Fig. 3a). After adjusting for height and weight there were no significant differences in BMC between the groups. There were no differences in BMC (Table

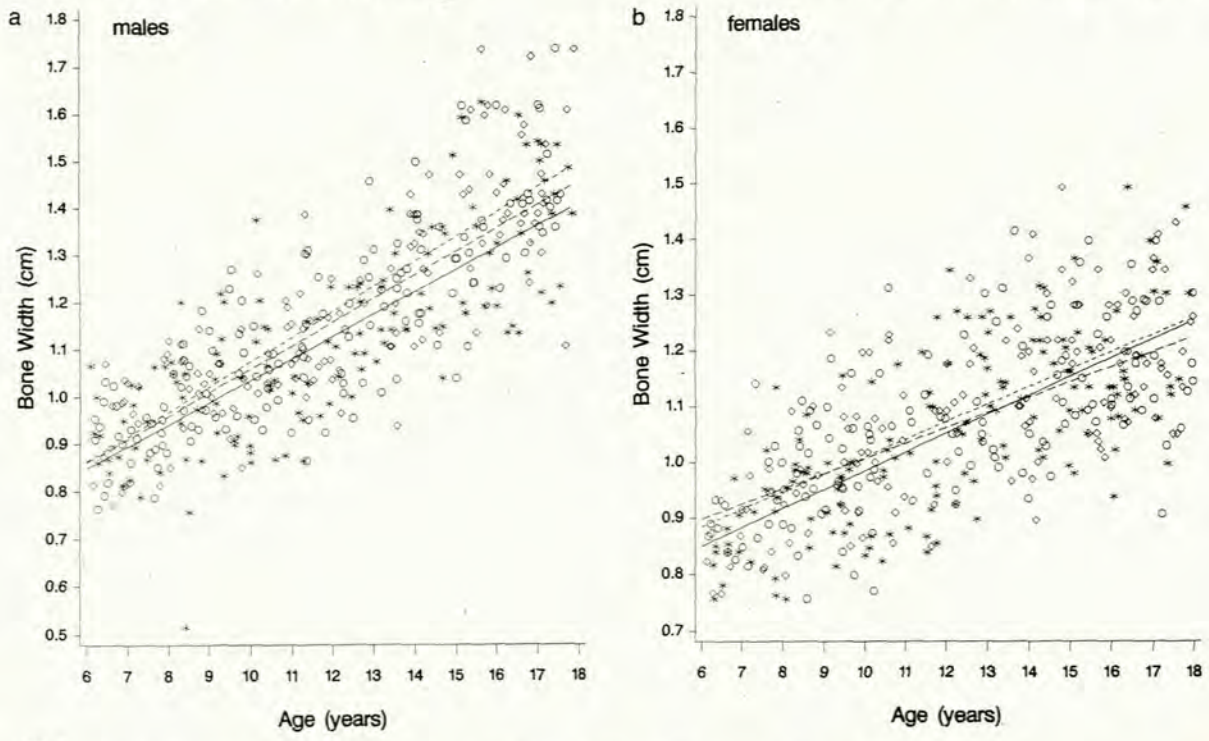

FIG. 2.
Relationship between BW and age: (a) males; (b) females (◇ = whites; ○ = coloured; ∗ = Indians).

IV and Fig. 3b) between girls of different ethnic groups. However, when adjusted for weight and height the BMC of coloured girls was greater than that for either white or Indian girls.

BMC/BW. The BMC/BW of white boys was significantly greater than that for either coloured or Indian boys (Table IV, Fig. 4a). Adjustment for height and weight resulted in the disappearance of any difference in BMC/BW between the ethnic groups for boys. There were no differences in BMC/BW between girls of different ethnic groups before adjustments were made for differences in weight and height. With these adjustments, the BMC/BW of coloured girls tended to be greater than that for either white or Indian girls.

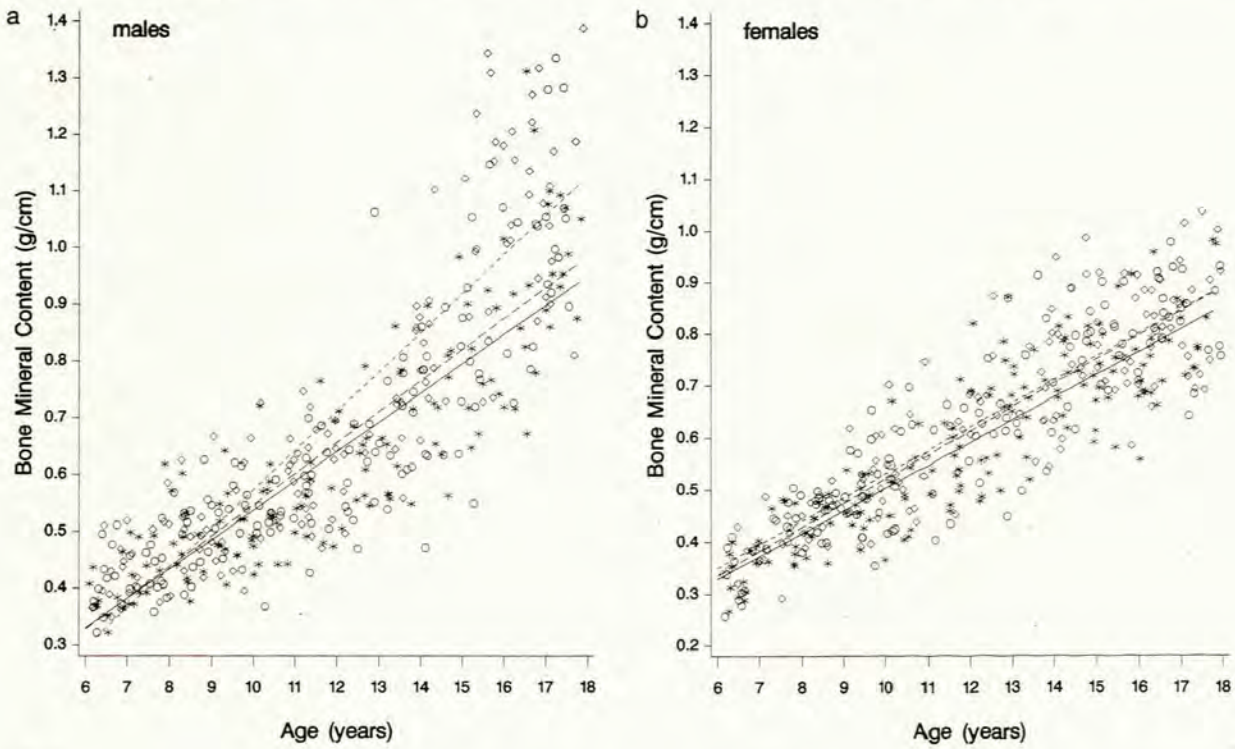

FIG. 3.
Relationship between BMC and age: (a) males; (b) females (◇ = whites; ○ = coloureds; * = Indians).

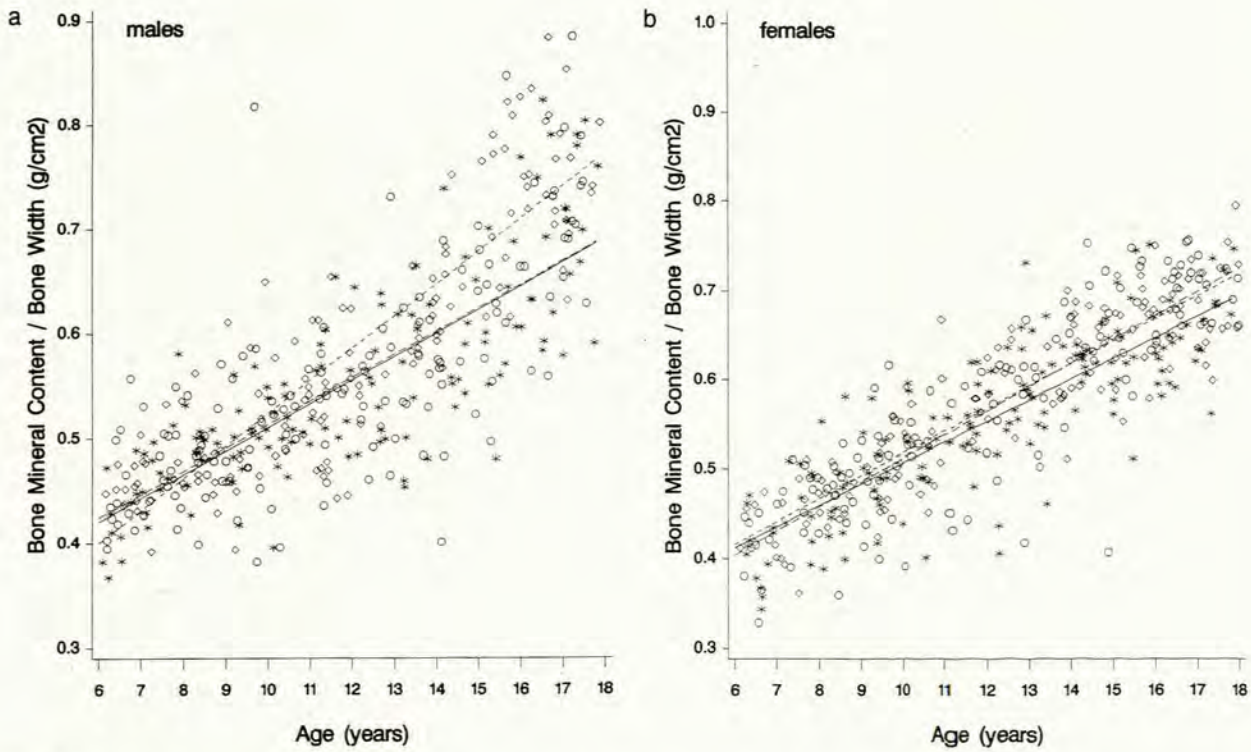

FIG. 4.
Relationship between BMC/BW and age: (a) males; (b) females (◇ = whites; ○ = coloureds; * = Indians).

Discussion

Postmenopausal and senile osteoporosis is a disease responsible for considerable morbidity and mortality among white women in South Africa. Recent research into the causes of osteoporosis has focused on the factors that influence peak bone mass. It is assumed that a higher peak bone mass in early adulthood results in a greater residual bone mass at menopause. In the present study, we examined the effect of ethnicity on peak bone mass by comparing bone mass in children and teenagers of three ethnic groups in South Africa. Before discussing these ethnic differences in bone mass, the anthropometric and pubertal findings, gender differences in bone mass and factors that influence bone mass will be discussed.

White children and teenagers were both taller and heavier than Indians and coloureds. This has been a feature of many other anthropometric studies in South Africa.[20,21] We believe that this is largely a consequence of socio-economic and nutritional differences between the groups. In the present study white children were drawn from private schools, which serve upper middle class communities, whereas Indian and coloured children were drawn from government schools located in working and lower middle class communities respectively.

There were no statistically significant differences in the age of onset of the various stages of puberty between the ethnic groups for either boys or girls. Although Indian boys enter stage two of pubic hair development somewhat earlier than white or coloured boys, they tend to achieve full maturity somewhat later than white and coloured boys. There are few published studies of pubertal development of South African children,[22] and to our knowledge no published data on pubertal development in South African boys exist at all. The present data do not bear out the prevailing impression that urban Indian and coloured children have delayed puberty in relation to white children.

BW and BMC were greater in boys than in girls, but BMC/BW did not differ significantly between the sexes. This suggests that although boys have larger bones than girls, actual bone mineral per unit volume is similar between the sexes.

Regression analysis found weight to be the most consistent factor determining bone mass. Height was significantly related to BMC/BW in all children (except coloured boys) and to BMC in girls. However, height and weight were highly correlated (as expected in growing children), and the effect of one may mask the effect of the other. Skin-fold thickness was negatively correlated to BW and BMC in all children when the effect of weight was taken into account. It was only positively correlated to BMC/BW in Indian girls. The general negative influence of skinfold thickness on bone mass has been reported by a number of researchers.[23-25] Our explanation for this negative influence is that for a given weight lean body mass (measure of muscle mass) has a greater influence on bone mass than body fat. In girls the time since onset of menarche was positively and significantly correlated to BMC and BMC/BW, but not to BW. The observed BMC and BMC/BW were greater than that predicted by the regression equation in prepubertal girls. The observed BW, however, was significantly lower than predicted BW. In girls, the overall effect of puberty therefore appears to be more pronounced on BMC and BMC/BW than on BW (a finding in black girls as well). In boys, testicular volume was positively correlated to BMC/BW in all the groups, to BMC in coloured and Indian boys, and to BW in Indian boys. The observed BMC and BMC/BW values were significantly greater than predicted values, whereas the observed BW measurements were less than predicted. In males, as in females, puberty therefore appears to exert a predominant effect on BMC and BMC/BW and a minimal effect on BW, possibly indicating that mineralisation increases despite a slowing of bone growth with advancing puberty.

Before adjusting for height and weight, all the bone measurements tended to be greater in white than in Indian or coloured girls, but none of these differences were statistically significant. After adjusting for height and weight, coloured girls emerged with significantly greater BMC and BMC/BW than either white or Indian girls.

White boys had significantly greater BW than Indian boys and greater BMC and BMC/BW than Indian or coloured boys. After adjusting for height and weight these differences all disappeared and only coloured boys had significantly greater BW than white boys. Ethnic differences in weight- and height-adjusted bone mass therefore appear largely to be confined to females, with coloured girls having greater BMC and BMC/BW than white or Indian girls. It is paradoxical that coloured girls should have greater weight- and height-adjusted BMC than white girls, since it is presumed that they consume less calcium than white girls. These differences in bone mass, however, cannot simply be attributed to genetic-racial factors; physical activity and hormonal differences, for example, may also play a role.

Wagener and Hough,[26] using magnification radiogrammetry, also found greater bone width and cortical thickness (the equivalent of BMC) in white than in coloured females aged 10 - 80 years. The Barnett-Nordin index (the equivalent of BMC/BW) was comparable between the two groups, however. Although epidemiological surveys of osteoporosis in South Africa have not been conducted, the prevailing impression is that osteoporosis is a disease that largely affects white and Indian women, while coloured women have an intermediate and black women a low incidence of the disease. This would tend to correlate with findings on height- and weight-adjusted BMC in girls, with coloured and black girls having the greatest and white and Indian girls the smallest BMC. However, we believe that these small differences in BMC do not adequately explain the large differences in the incidence of osteoporosis between the ethnic groups. Other factors that may play a role could be: (*i*) a greater increase in BMC in black and coloured females after closure of the epiphyses, during the period of bone consolidation; (*ii*) greater physical activity in black and coloured females throughout adulthood, which may slow the rate of bone attrition; (*iii*) differences in the age of onset and duration of menopause; and (*iv*) differences in the rate of bone loss after the menopause.

In conclusion, on examining the effect of ethnicity on bone mass during the period of bone growth we found height- and weight-adjusted appendicular bone mass to be similar in boys of different ethnic groups, but greater in coloured than in white or Indian girls. This may be an incipient difference that increases during the period of bone consolidation. Other factors, such as physical activity, diet and hormonal differences, have also to be examined in order to develop a more comprehensive understanding of ethnic differences in the incidence and prevalence of osteoporosis.

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