

Bone density in black and white South African women: contribution of ethnicity, body weight and lifestyle

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Abstract

Summary Ethnic differences in bone mineral density (BMD) between healthy adult black and white South African women were studied. Higher BMD was only noted at the femoral sites in black women. Body weight significantly impacted these findings. A lower fracture risk at all skeletal sites cannot be assumed in black South African (SA) women.

Purpose Bone mineral density (BMD) varies amongst women of different ethnicities. African-Americans have higher BMD at all skeletal sites compared with whites. On the African continent, bone density studies suggest site-specific ethnic differences in BMD. To examine the contribution of body weight and lifestyle characteristics to ethnic differences in BMD between adult black and white South African women, we assessed lumbar spine (SBMD), femoral neck (F_NBMD) and total femoral BMD (F_TBMD) by dual-energy X-ray absorptiometry (DXA) in 184 black and 143 white women aged between 23 and 82 years.

Methods BMDs were compared amongst pre- and postmenopausal blacks and whites before and after adjustment for covariates with significant univariate association with BMD. Volumetric bone mineral apparent density (BMAD) of the spine and femoral neck was also calculated to account for ethnic differences in bone size.

Results Before adjustment, SBMD was lower ($p < 0.05$), F_TBMD similar and F_NBMD ($p < 0.01$) higher in premenopausal black women. Similar SBMD, but significantly higher BMD at the femoral sites ($p < 0.01$), was noted in postmenopausal

blacks compared with whites. Amongst anthropometric measures and lifestyle factors, only adjustment for weight significantly altered these observed ethnic differences in bone density. After adjustment for weight, SBMD remained lower in premenopausal blacks and became lower in young postmenopausal blacks. Weight adjustment eliminated all ethnic differences in proximal femoral BMD measurements, with the exception of F_NBMD that remained higher in younger postmenopausal blacks. Before adjustment, calculated SBMD was similar and F_NBMAD consistently higher in blacks in all the menstrual groups. Adjustment for weight did not alter these findings.

Conclusion Most of the observed ethnic difference in BMD was explained by differences in body weight between black and white SA women. The higher femoral BMD in older blacks may explain the lower hip fracture prevalence in black South African women. The lower SBMD in pre- and postmenopausal black women in this study suggests that factors other than BMD should be considered to explain a lower vertebral fracture prevalence in blacks, if a lower fracture prevalence does indeed exist.

Keywords DXA · Osteoporosis · General population studies · Ethnicity

Introduction

Ethnic differences in bone mineral density (BMD) and fracture risk are well recognized. People of African ancestry have a lower incidence of fragility fracture than Caucasians as shown by studies on the African continent [1–3] and in the USA [4–7]. Fracture data relating to populations on the African continent are, however, limited, old and mostly confined to reports on non-vertebral fracture prevalence. Recent radiological assessment of prevalent vertebral fractures has suggested that the difference in vertebral fracture prevalence between elderly African-Americans (AA) and Caucasians

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may be considerably smaller (only 1.3 times higher) than what is previously reported in population studies [7].

Higher BMD in both the axial and appendicular skeletons has been consistently and repeatedly documented in African-American women compared with their white counterparts [4, 8–12], and these differences may account for their lower incidence of osteoporotic fractures at all skeletal sites [4–7]. Some of the ethnic differences in BMD may be due to ethnic differences in bone size that produce a scale artefact when BMD is measured by two-dimensional areal absorptiometry [13, 14], but important ethnic differences in BMD remain after adjustment for such artefacts [8, 9, 12]. On the African continent, data on greater bone density in blacks compared with whites are not nearly as convincing. Limited studies conducted in West African populations [2, 15–17] and in selected South African female cohorts [18, 19] have reported similar lumbar spine BMD, but higher femoral bone density in black women compared with whites.

It is expected that the shared genetic phenotype of black populations in America and on the African continent [20] will ensure comparable bone mineral density in these populations and thus protect them against osteoporosis and fragility fractures in a similar fashion. Attainment of peak bone mass and subsequent bone loss is, however, the result of an interplay between genetics and the environment. Exposure to adverse environmental factors may, in part, explain why black populations on the African continent do not realize their genetic potential at all skeletal sites.

The aims of the present study were to study BMD in adult black and white pre- and postmenopausal South African women and to evaluate the impact of lifestyle characteristics and anthropometry, especially total body weight, on ethnic differences in bone density.

Materials and methods

Study population

The study was descriptive and cross sectional. The study population consisted of a convenience sample of 184 black and 142 white premenopausal and postmenopausal South African women between the ages of 23 and 82 years. Volunteer subjects were recruited by word of mouth and through local church and community centres from the geographical area normally supplied of medical care by the Tygerberg Academic Hospital near Cape Town. Black and white races were determined by self-declaration, and all women were residents in the Western Cape for the majority of their adult lives. Due to known socioeconomic and anthropometric differences between the two ethnic groups, recruitment aimed to include a representative sample of black and white SA females

and did not specifically stratify subjects based on socioeconomic status or anthropometry.

Subjects were excluded if they had known metabolic bone diseases, suffered from diseases (e.g. endocrinopathies, malabsorption syndromes, malignancies, chronic alcoholism, renal or hepatic dysfunction), were taking medications (e.g. postmenopausal oestrogen therapy, glucocorticoids, anticonvulsants and any bone specific agent) known to affect bone metabolism or if they were pregnant or lactating. Subjects were classified as premenopausal ($n=163$) if they reported monthly menstrual bleeding during each of the three months preceding study entry and were only eligible for study entry if they reported a regular menstrual cycle. Subjects with either a clinical menopause (cessation of menses for >1 year) and/or chemical menopause (FSH values greater than 40 mIU/l) were defined as postmenopausal ($n=163$).

Written informed consent was obtained from each subject, the research complied with the World Medical Association Declaration of Helsinki—ethical principles for medical research involving human subjects—and the study was approved by the Ethical Review Board of the Faculty of Medicine, University of Stellenbosch.

Demographic data

A standardized interviewer-administered questionnaire was used to assess the following parameters with a potential impact on BMD: age (years), physical activity (a numerical score 0–5 based on active living, in-house and recreational physical activity), alcohol intake (units per week, a unit being equivalent to 28 g alcohol), cigarette smoking (expressed as ever, current or never and number of pack years), calcium intake (mg/day, dietary recall obtained by a qualified dietician during a personal interview) and a gynaecological history (age at menarche (years), number of prior pregnancies, breastfeeding, the use of oral or injectable hormonal contraception and menopausal status).

Anthropometry

All the anthropometric measurements were made by a single observer. All subjects were weighed on the same balanced beam scale. Height was measured with a stadiometer with a sliding headpiece to increase the accuracy of the reading. Waist circumference was determined in the erect position through a point one third of the distance between the xiphoid process and the umbilicus. Hip circumference was assessed in the erect position, through a point 4 cm below the superior anterior iliac spine, and elbow breadth was measured with a sliding calliper to the nearest 0.1 cm, at the point of the greatest breadth across the joint. Body mass index (BMI) was calculated as $\text{weight}/(\text{height})^2$ in kilogramme per metre squared [21].

Densitometry

Bone mineral content (BMC), bone area (BA) and bone mineral density (BMD) of the lumbar spine (L1–L4) and proximal femur were quantitated by employing dual-energy X-ray absorptiometry (Hologic DXA). A spine phantom was scanned weekly to determine the intrinsic coefficient of variation of the machine—this varied by less than 1 %. A single trained DXA technician performed scans on all study subjects, and the intra-operative variation was found to be less than 2.5 %

Bone mineral density was expressed as an absolute value (g/cm^2) in all menstrual groups and as a deviation from the norm, defined as a T-score, in postmenopausal women only. We used the uniform NHANES III reference database for whites [22] to calculate T-scores for both ethnic groups. We used the WHO criteria [23], based on T-scores, to diagnose osteopenia and osteoporosis in postmenopausal women.

Areal BMD measurements by DXA introduce a scale artefact that causes small bones to have lower areal BMD than larger bones. When comparing people from different ethnic groups with potential differences in bone size, BMD differences may thus be more apparent than real. This scale artefact was reduced by expressing BMD as BMAD, a calculated three-dimensional variable that helps account for differences in bone size. BMAD at the lumbar spine (in g/cm^3) was calculated as the mean BMC/(mean area)^{3/2} using the method of Carter et al. [13]. BMAD at the femoral neck (in g/cm^3) was calculated as the BMC/(area)² using the method of Katzman et al. [14].

In an attempt to assess ethnic differences in BMD at a time of expected peak BMD and following the impact of ageing, bone density was measured in premenopausal (aged 23–46 years), early postmenopausal (aged younger than 60 years with clinical or chemical menopause) and late postmenopausal subjects (aged 60 years and older). To control for adiposity, data was also analyzed by dividing pre- and postmenopausal subjects into weight subgroups, i.e. a subgroup with normal-to-low body mass index ($\text{BMI} < 25 \text{ kg}/\text{m}^2$) and a subgroup defined as overweight ($\text{BMI} \geq 25 \text{ kg}/\text{m}^2$) [21].

Statistical analysis

The statistical analysis was conducted by a qualified statistician (MK) using Statistica 7.1 software. Cross tabulation and the chi-square test were used to compare categorical variables. Spearman correlation was used for comparing continuous variables. One-way analysis of variance and analysis of covariance were used for comparing measurements between groups. A probability value (p) ≤ 0.05 was used as guideline for determining statistical significance. For all skeletal sites, BMDs and BMADs were first compared between the ethnic subgroups by ANOVA before adjustment for covariates. To

determine whether observed ethnic differences in bone mineral status were due to ethnic factors, the differences were re-compared after adjustment for certain covariates. Analysis of covariance was performed to identify covariates with significant univariate association with lumbar and femoral BMD and BMAD. For the premenopausal subjects, covariates included ethnicity, age, weight, height, daily calcium intake, pack years of smoking, alcohol intake, physical activity, age at menarche, hormonal contraception and number of prior pregnancies. For the postmenopausal subjects, covariates included years since menopause in addition to the abovementioned. For post hoc testing, the Bonferroni test was used. To evaluate potential ethnic differences regarding the association of BMD parameters with age, a general regression model was used including age and race \times age interactions.

Results

Clinical demographic characteristics

Table 1 shows baseline characteristics for the DXA cohort within the different ethnic and menstrual groups. Blacks were shorter and heavier with greater BMIs than whites. The weight difference was accentuated with ageing with an average 14-kg difference in weight between older black and white women. Blacks reached menarche at a later age and had greater number of pregnancies. A younger age at menopause and more years since menopause were only observed in the younger postmenopausal black women compared with whites. Blacks preferred progestogen-only injectable contraception, and ever use was mostly reported by the younger black females, whereas whites almost exclusively used oral oestrogen-containing contraception. Dietary calcium intake was significantly lower in blacks; they smoked less but were also less active post menopause. Mean alcohol consumption was low and comparable between the two ethnic groups.

The baseline clinical characteristics of the normal-low and overweight groups are shown in Table 2. The majority of black premenopausal females were overweight (74 %), whereas most white women had BMIs in the normal-to-low BMI range (62 %). In the normal-to-low BMI subgroup, there was no ethnic difference in mean BMI, but black females were significantly smaller with lower weight and height. The overweight premenopausal blacks were significantly heavier with greater BMIs than whites. The waist-hip ratio was similar in premenopausal normal weight and overweight blacks and whites. Based on BMI, the majority of both postmenopausal blacks (77 %) and postmenopausal whites (59 %) were categorized as overweight. In the normal-low weight postmenopausal women, the mean BMI was significantly higher in postmenopausal blacks. Although blacks tended to be heavier

Table 1 Anthropometric, lifestyle and menstrual data

Clinical characteristics	Premenopausal			Postmenopausal		
	<60 years			≥60 years		
	Blacks	Whites	Blacks	Whites	Blacks	Whites
<i>N</i>	87	76	49	35	48	31
Age (year)	37±8	39±7	52±6	52±5	68±6	70±5
Height (cm)	160±6*	167±6	160±7*	166±7	159±6	160±7
Weight (kg)	79±21*	69±15	80±19*	71±17	86±19*	72±15
BMI (kg/cm ²)	31±8*	25±5	32±8*	26±6	34±8*	28±5
Waist/hip ratio (cm)	0.84±0.1*	0.78±0.1	0.87±0.1*	0.79±0.1	0.90±0.1*	0.88±0.1
Age at menarche (years)	15±3*	13±2	14±2*	13±2	14±2*	13±1
Menopause age (years)			46±5*	49±4	49±5	49±5
Years since menopause			7±5*	4±4	19±8	21±7
Calcium intake (mg/day)	594±298*	876±270	597±237*	879±230	667±304*	821±272
Smoking (pack years)	0.6±1.8	3.8±18	1.6±4.7*	5±11	0.17±1*	8.9±14.1
Alcohol (U/week)	3.8±8.8*	4.2±5.3	3.7±11	2.9±5.1	1.4±4.2	1.8±3.8
PA score (0–4)	2.7±0.9	2.8±1	2.4±1*	3.1±0.9	1.9±0.9*	2.7±0.8
Family history (%)	1	28	2	29	0	13
OCP ever use (%)	17	72	16	54	29	30
DP ever use (%)	45	3	33	6	6	2
No. of pregnancies (<i>n</i>)	3±2*	2±1	3±2*	2±1	6±3*	4±2
Breastfeeding + (%)	70	58	78	62	88	68

Values reported are the mean±SD except where otherwise stated

PA physical activity, OCP oral contraceptives, DP depot provera

**p* value ≤0.05 (black vs. white)

and shorter, the difference in weight and height between the two ethnic groups was not significant. All the anthropometric

variables were significantly higher in the overweight postmenopausal blacks compared with whites.

Table 2 Anthropometric data in premenopausal and postmenopausal women in normal-to-low BMI and overweight subgroups

Characteristics	Normal-to-low BMI subgroup (BMI<25 kg/m ²)		Overweight subgroup (BMI≥25 kg/m ²)	
	Blacks	Whites	Blacks	Whites
Premenopausal				
<i>N</i> (%)	23 (26)	47 (62)	64 (74)	29 (38)
Age (year)	35±9*	39±6	37±8	37±7
Height (cm)	157±5*	167±6	161±6*	167±7
Weight (kg)	55±7*	61±6	87±7*	83±14
BMI (kg/cm ²)	21.9±1.9	21.9±1.8	33.8±6.4*	29.6±4.2
Waist/Hip ratio (cm)	0.78±0.06	0.77±0.05	0.85±0.09	0.81±0.08
Postmenopausal				
<i>N</i> (%)	22 (23)	27 (41)	75 (77)	39 (59)
Age (year)	60±10	58±11	60±9	61±10
Height (cm)	162±6	164±8	159±7*	162±7
Weight (kg)	61±6	59±8	90±17*	80±15
BMI (kg/cm ²)	23.4±1.8*	21.9±1.7	35.8±7*	30.6±2.4
Waist/hip ratio (cm)	0.83±0.1*	0.77±0.1	0.90±0.1*	0.86±0.1

Values reported are the mean±SD

**p* value <0.01 (black vs. white within weight subgroup)

Lumbar spine bone mineral density

Mean lumbar spine bone mineral content (SBMC), lumbar spine bone area (BA) and unadjusted lumbar spinal bone mineral density (SBMD) were significantly lower in premenopausal blacks compared with whites (Table 3). Univariate tests of significance identified ethnicity, body weight ($p<0.01$) and height ($p<0.01$) to be significantly associated with SBMD. After adjustment for weight as a covariate, mean SBMD remained significantly lower in the black cohort ($p<0.01$).

In postmenopausal women, mean SBMC was similar in the blacks and whites, spine BA was significantly lower in the black females ($p=0.01$) and unadjusted mean SBMD was similar in both the early and late postmenopausal black and white women. In the early and late postmenopausal groups, body weight ($p<0.01$) was positively associated with SBMD. After adjustment for weight as a covariate, SBMD was significantly lower in the black females compared with whites in the early postmenopausal group ($p=0.01$), whereas SBMD remained similar in the late postmenopausal cohorts ($p=0.18$). Mean SBMD in the early and late postmenopausal black groups was near identical, but tended to be lower in the late postmenopausal white female group compared with the early postmenopausal white group ($p=0.07$). This may suggest that, compared with blacks, more pronounced postmenopausal lumbar spine bone loss occurred in white females with ageing. SBMD was similar between black and white women in all the menstrual groups, before and after adjustment for covariates.

Weight was the only anthropometric variable that correlated significantly and positively with SBMD (Fig. 1) and

SBMD in all the menstrual subgroups. In the normal-low weight subgroup, SBMD was lower in the premenopausal and postmenopausal black females compared with whites ($p\leq 0.05$), but similar in the overweight group (Table 4). Within the two ethnic groups, significantly lower SBMD was documented in premenopausal and postmenopausal black women of normal weight compared to their overweight counterparts ($p\leq 0.01$). The mean SBMD of premenopausal and postmenopausal white women in the two weight subgroups was similar.

Femoral bone mineral density

The BMC of the femoral neck was similar in the premenopausal black and white subjects; the mean bone area (BA) of the femoral neck was significantly smaller in the black cohort, and this resulted in blacks having higher mean unadjusted femoral neck bone mineral density (F_N BMD) than whites (Table 5). Weight and height were found to be significantly ($p<0.01$) and positively associated with F_N BMD. After adjustment for weight as a covariate, the difference in mean F_N BMD between the two cohorts was non-significant. The BMC of the total femoral area tended to be lower; the mean total femoral BA was significantly smaller in blacks, with similar mean unadjusted total femoral bone mineral density (F_T BMD) in the two cohorts. Weight and height ($p<0.01$) were significantly associated with F_T BMD. Adjustment for weight did not alter these findings.

Femoral neck and total femoral measurements of the postmenopausal cohorts are also shown in Table 5. The F_N BMC was similar, the femoral neck BA significantly smaller and the mean unadjusted F_N BMD higher in blacks in the early and late

Table 3 Lumbar spine BMC, bone area, BMD and BMAD in premenopausal and postmenopausal black and white females

Spinal bone mass	Premenopausal		Postmenopausal			
			<60 years (early)		≥ 60 years (late)	
	Blacks	Whites	Blacks	Whites	Blacks	Whites
<i>N</i>	87	76	49	35	48	31
SBMC (g)	59.57 \pm 10.7*	66.57 \pm 11.2	52.8 \pm 13.6	58.5 \pm 13.6	53.4 \pm 13.4	57.1 \pm 14.8
S-BA (cm ²)	56.23 \pm 5.55*	60.38 \pm 5.23	55.7 \pm 5.2*	59.3 \pm 5.2	56.7 \pm 5.16*	60.7 \pm 7.2
SBMD (g/cm ²)						
Unadjusted	1.047 \pm 0.12*	1.099 \pm 0.13	0.940 \pm 0.18	0.988 \pm 0.17**	0.939 \pm 0.21	0.925 \pm 0.16
Adjusted: weight	1.036 \pm 0.12*	1.110 \pm 0.12	0.921 \pm 0.16*	1.015 \pm 0.16	0.911 \pm 0.18	0.968 \pm 0.18
SBMAD (g/cm ³)	0.139 \pm 0.01	0.141 \pm 0.02	0.125 \pm 0.01	0.127 \pm 0.01	0.126 \pm 0.02	0.118 \pm 0.02

Values reported are the mean \pm SD

BMC bone mineral content, BMD bone mineral density, BA bone area, BMAD bone mineral apparent density

* $p\leq 0.01$ (black vs. white within menstrual and age groups)

** $p=0.07$ (early postmenopausal white cohort vs. late postmenopausal white cohort)

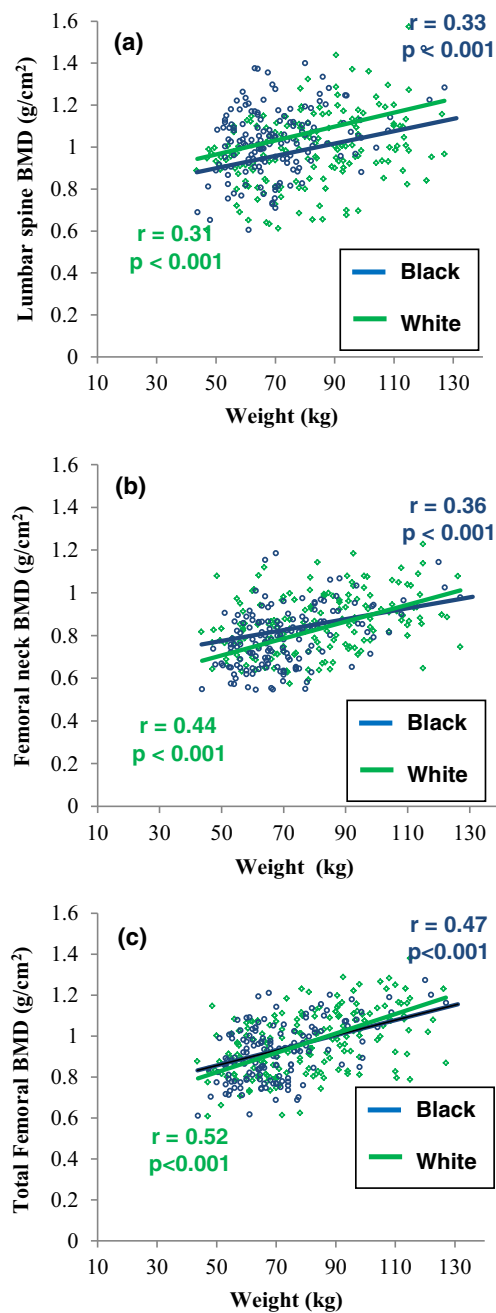


Fig. 1 Correlation between weight and BMD in the black and white study cohorts. Statistically significant positive correlation noted between weight and lumbar spine BMD (a), femoral neck BMD (b) and total femoral BMD (c) in both black and white women ($p < 0.001$)

postmenopausal groups. Likewise, F_T BMC was similar, total femoral BA smaller and mean unadjusted F_T BMD statistically significantly higher in blacks compared with whites in the younger postmenopausal group. In older postmenopausal subjects, the F_T BMC was, however, significantly higher and the total femoral BA similar. A significantly higher mean unadjusted F_T BMD, in accordance with the younger postmenopausal cohort, was also documented in the older

postmenopausal black women. Only weight ($p < 0.01$) was significantly associated with means F_N BMD and F_T BMD in the early postmenopausal subjects whereas age, weight, number of pregnancies and number of pack years smoked were significantly associated with proximal femoral bone density in older postmenopausal women. Only adjustment for weight significantly altered the ethnic differences in bone density (Table 5). Adjustment for weight diminished the ethnic difference in means F_N BMD and F_T BMD and resulted in similar mean F_T BMD between the younger postmenopausal cohorts and similar means F_N BMD and F_T BMD between the older postmenopausal women.

Femoral neck BMAD unadjusted and adjusted for covariates with significant association (younger postmenopausal groups: weight only; older postmenopausal cohorts: weight and number of pregnancies) was consistently higher in blacks (Table 5).

Similar to our observations with regard to SBMD and SBMAD, weight was the only anthropometric variable that consistently correlated significantly and positively with BMD (Fig. 1) and BMAD at the proximal femoral sites in all the menstrual subgroups.

Within the different weight groups in the premenopausal women, ethnic differences in femoral BMD were confined to significantly higher F_N BMD in blacks (Table 4). Both femoral measurements were significantly lower in the normal-low weight whites compared to the overweight white women ($p < 0.01$); this was not observed in blacks. In the postmenopausal women, femoral neck and total femoral BMD were higher in blacks compared with whites in the normal-low and overweight subgroups, although significance was not reached for F_T BMD in the normal-low weight subgroup. This may be partially due to small numbers of both black and white women in this weight subgroup. Both femoral BMD measurements were significantly lower in normal-to-low weight blacks and whites compared to their respective overweight counterparts.

Comparison of bone density across age and menstrual groups

A statistically significant negative correlation between age and BMD at all skeletal sites was present in the total black and white cohorts. A general regression model including age and race \times age interaction was employed to assess potential ethnic differences in the decline of BMD parameters with age. The race \times age interaction was significant ($p < 0.01$), indicating that the association of BMD parameters with ageing differed between blacks and whites with a steeper decline present in ageing white women (Fig. 2). Despite the cross-sectional nature of our study, the pattern of bone loss with ageing appeared to differ between the two racial groups (Table 6). The percentage decline in SBMD between the premenopausal and early postmenopausal black and white cohorts was near identical (9 and 10 %, respectively), but the older black

Table 4 SBMD, femoral neck BMD and total femoral BMD in premenopausal and postmenopausal weight subgroups based on BMI

	Bone density	Premenopausal		Postmenopausal	
		Blacks	Whites	Blacks	Whites
	SBMD (g/cm ²)				
	Normal-to-low weight	0.977±0.09***	1.095±0.13	0.854±0.12***	0.926±0.15
	Overweight	1.074±0.13	1.106±0.13	0.963±0.21	0.981±0.18
	F _N BMD (g/cm ²)				
	Normal-to-low weight	0.863±0.14*	0.814±0.12	0.766±0.11***	0.684±0.11***
	Overweight	0.909±0.11	0.888±0.11	0.829±0.14*	0.749±0.13
	F _T BMD (g/cm ²)				
	Normal-to-low weight	0.926±0.13	0.934±0.12	0.851±0.13**	0.816±0.12***
	Overweight	0.984±0.30	1.012±0.12	0.979±0.15*	0.910±0.15

Values reported are the mean±SD
 * $p \leq 0.05$ (black vs. white within menstrual and weight groups)
 ** $p \leq 0.05$ (black normal-to-low weight vs. black overweight group)
 *** $p \leq 0.05$ (white normal-to-low weight vs. white overweight group)

Table 5 Femoral BMC, bone area, BMD and BMAD in the premenopausal and postmenopausal black and white females

Bone density	Premenopausal		Postmenopausal			
			<60 years (early)		≥60 years (late)	
	Blacks	Whites	Blacks	Whites	Blacks	Whites
<i>N</i>	87	76	49	35	48	31
Femoral neck						
Femoral neck						
BMC (g)	4.73±0.78	4.60±0.74	4.41±0.80	4.02±0.78	4.23±0.84	3.95±0.99
Bone area (cm ²)	5.27±0.50*	5.47±0.42	5.26±0.37*	5.48±0.35	5.33±0.37**	5.55±0.50
BMD (g/cm ²)						
Unadjusted	0.896±0.12*	0.842±0.13	0.834±0.13*	0.736±0.13	0.794±0.14*	0.698±0.12
Adjusted: weight	0.885±0.11	0.855±0.11	0.818±0.11**	0.762±0.11	0.770±0.12	0.728±0.12
Adjusted: height	0.894±0.13*	0.845±0.13	–	–	–	–
Adjusted: age	–	–	–	–	0.788±0.13*	0.707±0.13
Adjusted: parity	–	–	–	–	0.802±0.13*	0.681±0.14
Adjusted: smoking	–	–	–	–	0.807±0.13*	0.677±0.13
Femur total						
BMC (g)	32.85±5.72	34.55±7.35	34.20±8.08	32.50±6.83	32.52±7.02**	31.25±7.09
Bone area (cm ²)	33.05±3.35*	35.75±4.78	35.03±4.19**	36.53±3.46	34.74±3.36	36.56±3.63
BMD (g/cm ²)						
Unadjusted	0.993±0.27	0.964±0.12	0.973±0.16*	0.890±0.15	0.931±0.15*	0.840±0.14
Adjusted: weight	0.979±0.12	0.979±0.12	0.946±0.11	0.925±0.11	0.907±0.13	0.877±0.13
Adjusted: height	1.005±0.14	0.952±0.14	–	–	–	–
Adjusted: age	–	–	–	–	0.926±0.15**	0.848±0.15
Adjusted: parity	–	–	–	–	0.943±0.15*	0.816±0.15
Adjusted: smoking	–	–	0.944±0.15*	–	0.944±0.15*	0.812±0.15
Femoral neck BMAD (g/cm ³)						
Unadjusted	0.170±0.03*	0.155±0.03	0.158±0.02*	0.134±0.02	0.150±0.03*	0.127±0.02
Adjusted: weight	–	–	0.155±0.02*	0.138±0.02	0.148±0.01*	0.130±0.01
Adjusted: age	0.170±0.03*	0.156±0.03	–	–	–	–
Adjusted: parity	–	–	–	–	0.151±0.02*	0.124±0.02

Values reported are the mean±SD

* $p \leq 0.01$ (black vs. white within menstrual and age groups)

** $p \leq 0.05$ but > 0.01 (black vs. white within menstrual and age groups)

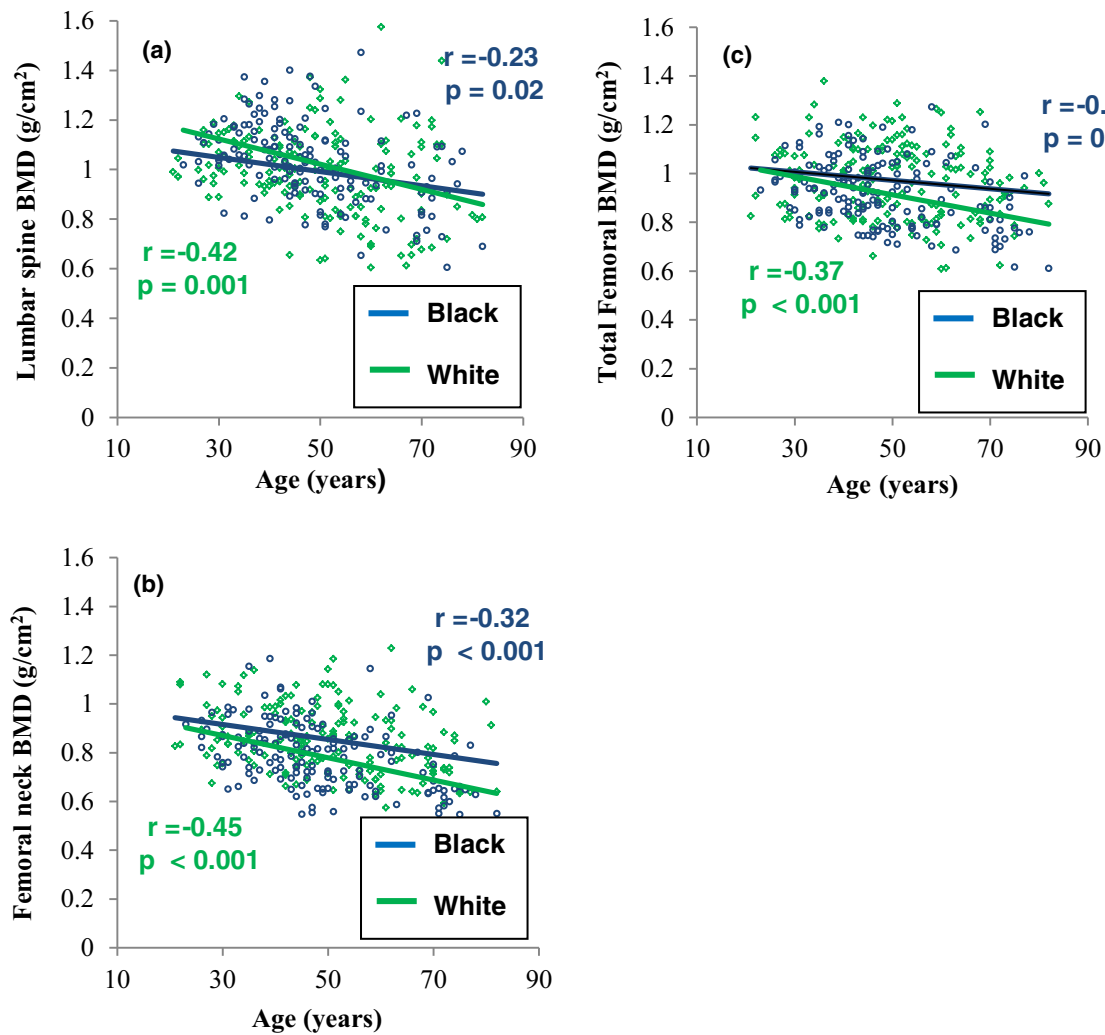


Fig. 2 Correlation between age and BMD in the black and white study cohorts. Significant negative correlation between age and BMD measurements at the lumbar spine (a), femoral neck (b) and total femoral (c) sites for blacks and whites ($p \leq 0.05$). The interaction effect of race \times age is

significant for proximal femoral sites indicating a sharper decline in BMD measurements at the proximal femur in ageing whites compared with blacks ($p < 0.001$)

females maintained their SBMD better compared with whites. Similar SBMD was thus noted in the late postmenopausal

black and white women despite the lower SBMD observed in premenopausal blacks. The percentage bone loss at the

Table 6 Bone loss with ageing in black and white cohorts

Ethnicity	Premenopausal	Percentage decline	Early postmenopausal	Percentage decline	Late postmenopausal
SBMD					
Blacks	1.047 \pm 0.12	9	0.940 \pm 0.18	0	0.939 \pm 0.21
Whites	1.099 \pm 0.13	10	0.988 \pm 0.17	6	0.925 \pm 0.16
Femoral neck BMD					
Blacks	0.896 \pm 0.12	7	0.834 \pm 0.13	5	0.794 \pm 0.14
Whites	0.842 \pm 0.13	13	0.736 \pm 0.13	5	0.698 \pm 0.12
Femoral total BMD					
Blacks	0.993 \pm 0.27	2	0.973 \pm 0.16	4	0.931 \pm 0.15
Whites	0.964 \pm 0.12	8	0.890 \pm 0.15	6	0.840 \pm 0.14

Values reported are the mean \pm SD. Percentage decline noted in bold

femoral neck and total femoral regions across the menopausal transition (i.e. between the premenopausal and early postmenopausal cohorts) was higher in whites (femoral neck region, 13 vs. 7 %; total femoral region, 8 vs. 2 %). Thereafter, a similar rate of decline in femoral BMD was noted in blacks and whites and ensured that black women maintained their significantly higher means F_N BMD and F_T BMD into old age.

Osteopenia and osteoporosis in postmenopausal women

A similar percentage of black and white postmenopausal women had spinal osteopenia as measured against a uniform white reference population (53 % of postmenopausal blacks and 44 % of postmenopausal whites), while 14 % of both blacks and whites met the diagnostic criteria for osteoporosis. Although a higher percentage of postmenopausal whites were osteopenic at the proximal femoral sites, a significant percentage of postmenopausal blacks also presented with femoral neck (35 %) and total femoral (28 %) osteopenia. Osteoporosis as defined by WHO criteria, and measured against a uniform white reference population, was confined to the white group affecting 11 % of the postmenopausal population.

Discussion

This cross-sectional study which compared the spine and hip BMD of black and white South African women, concluded that spine BMD was either lower or similar in blacks compared with whites, that proximal femoral BMD was higher in blacks and that bone loss with ageing was attenuated in blacks. The ethnic differences in BMD observed in this study were fully accounted for by differences in total body weight between blacks and whites. Furthermore, the attenuated loss of bone in blacks appeared to relate largely to the progressive increase in body weight in ageing black women. The lower SBMD in blacks was due to a lower peak SBMD in premenopausal women and contests the idea of genetic protection against osteoporosis at all skeletal sites in black South African women.

Site-specific differences in BMD have been reported in other female populations on the African continent. Studies conducted in The Gambia and other West African populations have documented lower or similar SBMD in African women compared with European subjects [2, 15–17, 24]. In the only two previous studies employing DXA measurements of BMD in adult black and white South African women, similar SBMD, but significantly higher femoral BMD, has been reported [18, 19]. Although a similar trend in BMD measurements at different skeletal sites was reported in these studies compared to ours, significant differences were also observed, for example, SBMD was lower in our premenopausal blacks

compared with whites, and the ethnic difference in femoral measurements was non-significant after adjustment for total body weight.

African-American women have higher BMD at all skeletal sites compared with whites [8–12, 25, 26], and most studies indicate that the higher BMD in adult African-American women is due to the attainment of a greater peak bone mass by early adulthood [8, 9, 11, 12, 25, 27]. It is thus generally accepted that the black skeleton is genetically protected against the development of OP and its consequences. South African blacks, similar to their American counterparts, may have a genetic tendency to greater BMD than whites, since both of these populations originated and migrated from West Africa [20]. The finding of lower SBMD in premenopausal blacks in the present study, however, argues against significant genetic protection in black South African women at all skeletal sites.

In this study, total body weight had a major impact on observed ethnic differences in peak BMD. The presence of a higher body weight eliminated ethnic differences in BMD at all skeletal sites, whereas a normal-low body weight unmasked site-specific ethnic differences in BMD in our study subjects. The finding of lower SBMD in premenopausal black women could be mainly attributed to lower SBMD in blacks with low-normal weight ($p < 0.01$). The SBMD of lower weight black women was also significantly lower than that of overweight blacks and suggests that a low body weight may serve as one of the most important risk factors for a low peak SBMD in blacks. A low body weight may, therefore, play a more important role than proposed genetic factors in determining ethnic differences in peak BMD at the spine in South African women. A significant association between spine BMD and other lifestyle factors such as a lower calcium intake and more frequent use of injectable contraception could not be demonstrated in our black study subjects, but this may be the result of a relatively small sample size.

Premenopausal blacks had greater proximal femoral neck BMD and similar total femoral BMD compared with whites. The higher femoral neck BMD was mostly accounted for by higher measurements in the low-normal weight subgroup, whereas no ethnic difference in proximal femoral BMD was noted in the overweight women. The higher femoral neck BMD in blacks in the low-normal weight group may suggest that genetic factors do play an important role at this specific skeletal site in blacks, affording protection despite adverse environmental factors. Higher BMD confined to the proximal femoral sites has been reported in black South African schoolchildren despite their lower socioeconomic status and exposure to numerous factors known to impact negatively on bone mass [28, 29]. This lends support to a protective genotype at the hip region in South African blacks similar to the African-American population.

Although this cross-sectional study was not designed to interpret longitudinal changes, apparent ethnic differences in the pattern of bone loss with ageing at both the hip and spine were observed. A steeper decline in BMD at all skeletal sites was noted in ageing white women, which reached statistical significance at the proximal femoral sites ($p < 0.001$) (Fig. 2). A slower decline in femoral BMD, especially during the menopausal transition period, and better-maintained spinal BMD in older blacks (Table 6) resulted in similar SBMD and progressively higher proximal femoral BMD in ageing black women.

Different patterns of bone loss in ageing black and white women, with a slower rate of cortical and trabecular bone loss in black women, have also been observed in previous multi-ethnic studies conducted in South Africa and the USA [18, 30–32]. The progressive increase in adiposity with ageing may be an important mechanism whereby black women maintained their BMD better into old age compared with whites. The ethnic difference in body weight was most pronounced in older women, and weight, similar to our finding in premenopausal women, was positively associated with BMD at all skeletal sites. The impact of body weight on BMD was further demonstrated by our finding of higher BMD, especially at the proximal femoral sites, in the overweight blacks and whites. Body weight may impact on patterns of bone loss via the mechanical loading effect of its lean mass component as well as the hormonal impact of its fat mass component [33–37]. Fat mass becomes the main determinant of endogenous oestrogen activity due to the increased conversion of androgens to estrogens after the menopause and may have a role in maintaining BMD in postmenopausal females as reported by others [34, 36, 37].

The higher proximal femoral BMD in our postmenopausal black women is in accordance with other South African and international studies [10, 18, 19, 26]. Differences in anthropometry, especially body weight or body mass index, have been reported to account for part of the difference in BMD between blacks and whites, both from South Africa and the USA [12, 18]. In the South African nurses' study, proximal femoral BMD remained significantly higher in postmenopausal blacks after correction for weight [18]. Finkelstein et al. [12] reported that adjustment for anthropometric and lifestyle factors, particularly body weight, reduced the magnitude of the difference in lumbar and femoral neck BMD between African-American and Caucasian women (unadjusted difference SBMD 7–12 %, adjusted difference 3–6 %, unadjusted difference F_N BMD 14–24 %, adjusted difference 6–9 %). Significant differences in BMD, however, remained, after correction for weight in all of these reports, whereas adjustment for body weight fully accounted for the ethnic differences in BMD between black and white women in the present study.

Clinical risk factors other than body weight may also impact on BMD and patterns of loss. The clinical risk profiles of black and white postmenopausal women differed, but a significant association was only noted between femoral BMD and parity (positive association) and pack years smoking (negative association) in older postmenopausal women. Correction for these clinical covariates did not significantly alter ethnic differences in femoral BMD. The mean calcium intake of postmenopausal blacks was lower compared with whites ($p < 0.01$), and physical activity was less well maintained amongst ageing blacks ($p < 0.01$). A significant association between calcium intake and physical inactivity and BMD could not be demonstrated in our postmenopausal cohorts. Again, this may be ascribed, at least in part, to the small sample size of our study, and a contribution of these lifestyle factors cannot be excluded.

Impact of bone size on BMD measurements

Lumbar spine and femoral neck bone area, as measured by DXA, were significantly smaller in black women compared with whites, a finding also reported in African-American women compared with Caucasian women [12]. Areal measurements may thus be inappropriately low in the black cohorts due to their smaller bone size. In the present study, partial corrections of bone size increased bone mineral measurements of the black women relative to whites and resulted in similar mean spinal BMAD and significantly higher mean femoral neck BMAD in premenopausal and postmenopausal black women before and after adjustments for covariates, including body weight.

Multi-ethnic studies in the USA reported that women with osteopenia or osteoporosis had an increased risk of fracture in every ethnic group, but the absolute risk of fracture at any given BMD differed between African-American women and white women [4, 5]. The estimated volumetric apparent bone density of the femoral neck is not regarded as superior to areal femoral BMD in the prediction of hip fracture in elderly postmenopausal white women [38]. Since women of different racial and ethnic groups have substantially different femoral neck sizes, BMAD might in fact be a better predictor than BMD of hip fracture in a more diverse population.

BMD and fracture risk in black and white postmenopausal females

Vertebral osteoporosis was present in 14 % of both black and white postmenopausal women, whereas femoral osteoporosis was confined to 11 % of the postmenopausal white population. The small/no ethnic difference in BMD at most measured sites cannot readily explain the apparent large difference in fracture risk previously reported in white and black South African women. Data pertaining to fracture prevalence in

black South African females are very limited and old and may not truly represent current fracture risk [1, 3]. Prospective studies are clearly needed to assess the true prevalence of vertebral and hip fracture in black and white SA women.

Our study had limitations. Conclusions drawn from this study were limited by the small sample size of 326 women, but data obtained in this cohort nonetheless do contribute to the current small knowledge pool regarding ethnic differences in BMD on the African continent. Assessment of BMD measurements across age and menstrual groups in this cross-sectional study did allow us to observe different trends with regard to BMD measurements in premenopausal females and preservation of BMD with ageing in black and white SA women. The cross-sectional study design, however, limited our ability to truly assess and interpret longitudinal changes and bone loss patterns in both ethnic groups. The apparent ethnic differences in bone mineral changes with ageing observed and documented in this study therefore need to be verified in prospective population-based studies. As participation was voluntary, selection bias may have occurred. We furthermore did not stratify patients based on socioeconomic status or anthropometry due to inherent differences in this regard between the two ethnic groups. We do, however, feel that our BMD data was obtained in a study sample that accurately reflects the broader premenopausal and postmenopausal white and black SA female population.

To conclude, this study has shown that black South African women have lower spine BMD than whites, that the higher proximal femoral BMD in blacks is fully accounted for by marked ethnic differences in body weight and that the observed attenuated bone loss in black females is related to their significantly higher body weight. Black South African women should not be regarded as genetically protected against the development of osteoporosis and should not be excluded from strategies aimed at prevention and early detection of this potentially debilitating disease. The modern tendency towards a lower ideal body weight in urbanized black societies may further increase the likelihood of suboptimal attainment of peak BMD and may impact on bone loss rates with potentially lower BMD in later life in the black populations of South Africa. Prospective studies are clearly needed to better define patterns of bone loss and vertebral and hip fracture prevalence in postmenopausal black and white SA women.

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Conflicts of interest None.

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