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IMPACT OF WEIGHT LOSS AND AEROBIC EXERCISE ON NUTRITION AND BONE MINERAL DENSITY IN AFRICAN AMERICAN AND CAUCASIAN POSTMENOPAUSAL WOMEN

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Abstract: *Background:* Weight loss is often recommended for obese women to reduce fat mass and the risk of developing chronic diseases, but may result in a reduction of bone mineral density (BMD). African Americans have greater BMD than Caucasians, but differences in the decrease in BMD between these races following weight reduction with and without exercise are unknown. *Objectives:* The purpose of this study was to investigate the hypothesis that Caucasian women would lose greater amounts of BMD than African American women after undergoing weight loss, but that the addition of aerobic exercise would attenuate the loss in both races. *Design:* Longitudinal. *Participants:* African American (n=34) and Caucasian (n=63), overweight and obese postmenopausal (age 45-80 years). *Intervention:* Six months of weight loss (250-350 kcal/days deficit) alone (WL) or in combination with aerobic exercise consisting of 3 days/week treadmill training at >85% of heart rate reserve for 45 min (AEX+WL). *Measurements:* Femoral neck, total femur, and lumbar BMD, VO2max, urinary calcium, and dietary intake. *Results:* African American women had a greater body weight, BMI, and BMD all sites and lower dietary protein and calcium intakes than Caucasian women (all $P<0.05$). Weight decreased 7.5% in both groups and VO2max increased only after AEX+WL (intervention effect, $P<0.001$). Both races lost ~1% of their femoral neck and total femur BMD following the interventions (P's<0.01). There were no race by intervention interactions. There was a trend for the women undergoing WL to lose greater femoral neck BMD than those in AEX+WL ($P=0.07$). There were no associations between changes in BMD and changes in VO2max, urinary calcium, or dietary intake. *Conclusions:* Our data indicate that despite beginning the interventions with greater BMD than Caucasian postmenopausal women, African Americans were not spared from losses of femoral neck and total femur BMD following six months of weight loss, but that addition of aerobic exercise to weight loss tends to attenuate the decreases in femoral neck BMD in both races.

Key words: Bone mineral density, weight loss, aerobic exercise, race, postmenopausal women.

Introduction

Excess body weight is thought to be protective against the decrease of muscle and bone observed with normal aging by providing increased skeletal loading and hormonal effects (i.e. estradiol) (1). Weight loss is often recommended for obese women to reduce fat mass and the risk of developing chronic diseases, such as diabetes, cardiovascular disease, and cancer. However, it also results in loss of lean mass and bone mineral density (BMD) (2, 3). Our group (2, 3) and others have reported that initiating exercise training during weight loss can prevent muscle and bone loss in predominately Caucasian women (4, 5). We have shown that the changes in cardiopulmonary fitness level (VO2max) and body composition measures (i.e. lean mass) observed following weight loss and exercise training are associated with changes in BMD (2, 3).

African American women have greater BMD, fat mass, and lean mass for height than Caucasian women (6), as well as a lower incidence of osteoporosis (7). Although the rate of decline of BMD increases in both African American and Caucasian women with age, the rate is twice as great in Caucasian compared to African American women (8, 9). Modifiable factors often observed to be different by race and known to affect BMD include serum hormones (i.e. 25-hydroxy vitamin D (25(OH)D), insulin-like growth factor-1 (IGF-1), and parathyroid hormone (PTH)) and dietary intake (i.e.

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protein and calcium). Identification of factors which contribute to racial BMD differences is important in order to combat decreases in BMD following weight loss.

The purpose of this study was to compare the changes in BMD following weight loss alone (WL) or in combination with aerobic exercise (AEX+WL) between African American and Caucasian postmenopausal women. We hypothesized that Caucasian women would lose greater amounts of BMD than African American women after WL, but that the addition of AEX+WL would attenuate the loss in both races. Additionally, this study examined whether racial differences in serum hormones and dietary intakes of protein and calcium were associated with baseline BMD, as well as whether any dietary changes following the interventions impacted changes in BMD by race.

Materials and Methods

Subjects

Healthy, overweight and obese, postmenopausal (age 45-80 years) women were recruited from the Baltimore area. At baseline, women were sedentary, participating in <20 minutes of aerobic exercise two times/wk, and weight stable (<2 kg weight change over past year). A medical history, physical examination, resting 12-lead electrocardiogram, and fasting blood profile were performed to exclude those with unstable medical conditions. Subjects with evidence of hypertension, hypertriglyceridemia, heart disease, cancer, liver, renal or hematological disease, orthopedic limitations, or medical conditions deemed to impact participation were excluded. All women signed University of Maryland Institutional Review Board approved informed consent forms.

Ninety-seven women, from a larger subset of individuals from a previously published paper (N=174) (10), were selected for analysis based upon complete dietary and BMD data. In addition to those that dropped out or were excluded due none-compliance to the interventions (data previously reported (10)), an additional six women were excluded due to incomplete BMD data. Fifteen (15%) women were taking a form of hormone replacement therapy, 48 (49%) were on a supplement containing calcium (Ca2+), and four (4%) were on bisphosphonates. All women continued to consume their respective supplement(s) though the study duration.

Study Design

Subjects were part of a larger trial of WL and AEX+WL. Subjects provided a food record prior to undergoing four weeks of dietary stabilization, where they met with a Registered Dietitian (RD) weekly to learn a heart healthy diet (i.e. <7% of diet as saturated fat, <2300 mg sodium, with more fruits, vegetables, and complex carbohydrates). Following dietary stabilization, subjects completed baseline testing (body composition, BMD, VO2max, urinary Ca2+, and serum hormones). Then, all subjects met weekly for six months with the RD to learn techniques for consuming a hypocaloric (250-350 kcal/d deficit), heart healthy diet. The average compliance for attendance to the weight loss classes was 86%. In addition, women in the AEX+WL group exercised 3 days per week at our facility using treadmills and elliptical trainers. Training programs were gradually progressed in duration and intensity until the participant was able to exercise at >85% heart rate reserve for 45 minutes. Each exercise session included a 5-10 minute stretching and warm-up phase and a 5-10 minute cool-down phase. Exercise sessions were supervised by exercise physiologists. The average compliance for attendance to the exercise sessions was 87%. Following the six month interventions, all baseline tests were repeated, with the exception of the serum hormones. As published previously (10), each intervention led to a significant loss of body weight, BMI, % body fat, lean and fat mass.

Cardiorespiratory Fitness

VO2 was measured by indirect calorimetry during a graded exercise test on a treadmill as previously described (10). VO2max was determined if two of the following criteria were met: respiratory exchange ratio ≥ 1.0, maximum heart rate >90% of age-predicted maximum (220-age), or a plateau in VO2 (<200 ml/min change). If such criteria were met, the highest level of VO2 was defined as VO2max. Eight of the 97 VO2max tests (8%) at the 6 month timepoint were not included in the statistical analysis due to failure to reach VO2max or a medical (i.e. orthopedic) condition that prohibited testing.

Dietary Intake

Dietary adherence to the heart healthy, hypocaloric diet was monitored weekly by the RD with review of dietary records, using the American Diabetes Association exchange list system. Five day food records (2 weekend and 3 weekday days) were analyzed using Nutritionist Pro (Axxya Systems, Stafford, TX) for average energy, macronutrient, and micronutrient intakes. Energy, protein, and Ca2+ intakes are reported.

Body Composition and BMD

Height and body weight were measured using a stadiometer and electric scale to calculate body mass index (BMI: weight [kg]/height [m^2]). A total body dual energy x-ray absorptiometry scan (DPX-IQ; LUNAR Radiation Corp., Madison,Wisconsin, USA) was performed at baseline and after WL and AEX+WL to determine lean mass, fat mass, and % body fat, as well as regional scans to determine BMD (g/cm^2) of the femoral neck, total femur, and lumbar spine (L1-L4).

Urinary Calcium and Serum Hormones

Participants were weight stable (±0.25 kg) and consumed two days of a heart healthy diet prior to urine and blood collections. While on this diet, subjects collected a 24 hour urine sample. Samples were analyzed for total daily urinary Ca2+ excretion by potentiometry utilizing a calcium ion selective electrode in conjunction with a sodium reference electrode (Synchron Clinical System, Beckman Coulter, Inc., Brea, CA).

Blood samples were collected via venipuncture in the morning (7:00-9:00 am) following a 12 hour fast. Serum samples were collected, allowed to clot at room temperature, and separated after centrifuging at 3,000 rpm for 15 min at 4°C. Samples were stored at -70°C until analysis. To eliminate interassay variation, samples were analyzed in the same assay and performed in duplicate. Serum 25-hydroxy vitamin D (25(OH)D) and insulin-like growth factor-1 (IGF-1) were measured by RIA (DiaSorin., Stillwater, Minnesota and Nichols Institute Diagnostics, San Juan Capistrano, CA, respectively) and parathyroid hormone (PTH) by IRMA (Nichols Institute Diagnostics, San Juan Capistrano, CA).

Statistical Analysis

The effect of the intervention (WL versus AEX+WL) was compared using ANOVA: change = baseline value + intervention group + racial group + intervention*racial group. When the intervention*racial group interaction was not significant, it was dropped from the model and the analysis was re-run. Paired t-tests were used to determine changes from baseline. Pearson correlations and partial correlations were used to assess relationships between key variables. Statistical significance was set at a two-tailed P<0.05. Data were analyzed using SPSS (PAWS Statistics, Version 18, Chicago, IL). Results are expressed as mean ± SEM.

Results

Baseline Characteristics (Table 1)

As anticipated, African Americans had a greater body weight, BMI, lean mass, fat mass, and lower relative VO2max than the Caucasian women (all P<0.05). There was no difference in % body fat and absolute VO2max between groups. Femoral neck, total femur, and lumbar spine BMD were 7, 6, and 9% lower in Caucasian than African American women, respectively (all P<0.05). Serum 25(OH)D concentrations were 35% lower in African American than Caucasian women (P<0.01), but there was no racial difference observed for IGF-1 or PTH levels. There was a trend for lower urinary Ca2+ excretion in African American than Caucasian women (P=0.07). Dietary protein and Ca2+ intakes were 17% and 27% lower in African American than Caucasian women, respectively (both P<0.01). Removal of the women on hormone replacement therapy or bisphosphonates did not change the direction of the study results.

Table 1
Physical characteristics of the African American and Caucasian groups at baseline

	African American N=34	**Caucasian N=63**
Age (yrs)	59±1	62±1
Weight (kg)	92±2**	84±2
BMI (kg/m^2)	35±1**	32±1
Body Fat (%)	48.3±0.8	46.5±0.6
Lean Mass (kg)	44.9±1.1*	42.1±0.8
Fat Mass (kg)	44.9±1.7*	39.5±1.3
VO2max (mL/kg/min)	17.4±0.9*	19.6±0.6
VO2max (L/min)	1.58±0.08	1.63±0.05
Femoral Neck BMD (g/cm^2)	0.987±0.024**	0.916±0.015
Total Femur BMD (g/cm^2)	1.038±0.023*	0.974±0.016
Lumbar Spine BMD (g/cm^2)	1.262±0.035**	1.144±0.022
25(OH)D (ng/ml)	17±1**	26±1
PTH (pg/ml)	59±6	51±3
IGF-1 (ng/ml)	142±11	148±6
Urinary Ca2+ (mg/d)	115±13¥	146±10
Caloric Intake (kcals/d)	1847±64	1876±51
Dietary Protein (g/kg/d)	0.80±0.04**	0.96±0.03
Dietary Ca2+ (mg/d)	621±52**	849±56

Values are means ± SEM. Significantly different than Caucasians: *P<0.05, **P<0.01, ¥P=0.07.

Baseline Correlations

Femoral neck BMD was negatively associated with age in the total sample (r=-0.37, P<0.01), as well as in each group alone (African Americans: r=-0.56, P<0.01 and Caucasians: r=-0.25, P<0.05). As shown previously by our group (2, 3, 11), weight, BMI, % body fat, and lean and fat mass were positively associated with femoral neck, total femur, and lumbar spine BMD. These associations remained after controlling for age and race. VO2max was associated with femoral neck BMD (r=0.30, P<0.01). Urinary Ca2+ excretion, serum 25(OH)D, IGF-1, and PTH, and nutritional intakes were not associated with baseline BMD at any site.

Table 2
Changes from baseline by intervention and race following 6 months of WL or AEX+WL

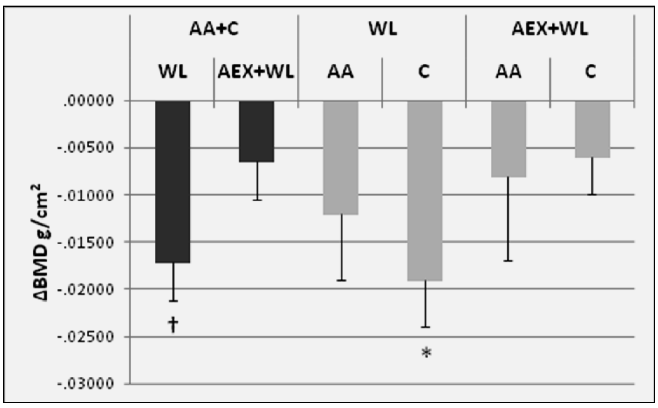
	Intervention Effect	WL		AEX+WL	
		African American (n=15)	Caucasian (n=30)	African American (n=19)	Caucasian (n=33)
ΔWeight (kg)		-6.6±0.65**	-7.0±0.7**	-6.2±0.6**	-7.3±0.6**
ΔBMI (kg/m2)		-2.5±0.3**	-2.7±0.3**	-2.4±0.2**	-2.8±0.2**
ΔBody Fat (%)	†	-2.1±0.5**	-2.7±0.4**	-3.7±0.6**	-3.6±0.5**
ΔLean Mass (kg)	‡	-2.0±0.6**	-1.8±0.4**	-0.4±0.4	-1.1±0.2**
ΔFat Mass (kg)		-5.2±0.6**	-5.5±0.6**	-5.5±0.6**	-5.8±0.7**
ΔVO2max (L/min)	‡	-0.02±0.07	-0.03±0.03	0.23±0.06**	0.16±0.04**
ΔLumbar BMD (g/cm2)		-0.010±0.013	0.002±0.008	-0.012±0.011	-0.006±0.009
ΔUrinary Ca2+ (mg/d)	¥	-59.07±16.73**	-11.69±13.91	12.07±31.61	0.05±8.6
ΔCalories (kcals/d)		-347±111**	-221±81**	-226±75**	-295±101**
ΔProtein (g/kg/d)	†	0.13±0.18*	0.12±0.05*	-0.03±0.09	-0.02±0.06
ΔDietary Ca2+ (mg/d)		46.2±64.9	27.0±115.2	-12.1±102.2	-56.3±65.9

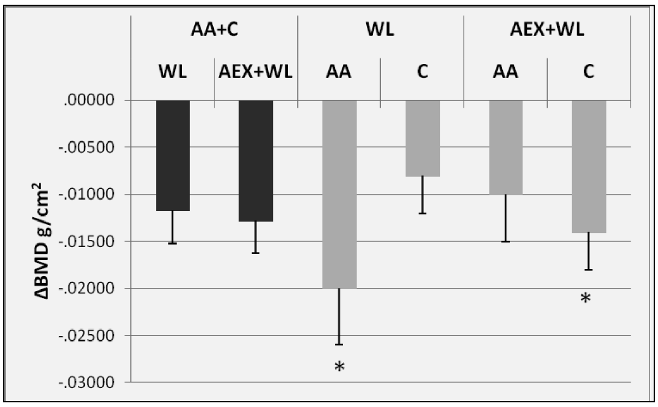
Values are means ± SEM. Intervention Effect: †P<0.05, ‡P<0.01, ¥P=0.07. Change from baseline: *P<0.05, **P<0.01. FN= femoral neck, TF= total femur.

Race and Intervention Effects

Changes in body composition and BMD may be viewed in Table 2. Overall, the interventions, regardless of race, lead to a 7.5% weight loss, a 1.1% decrease in femoral neck BMD, and a 1.3% decrease in total femur BMD (P<0.01) (Figure 1). According to World Health Organization definitions of osteopenia and osteoporosis (12), 26, 12, and 15% of African American women and 27, 25, and 22% of Caucasian women were osteopenic at the femoral neck, total femur, lumbar spine, respectively. Five percent of Caucasian women were osteoporotic at the lumbar spine, while no osteoporosis was present in African Americans. These percentages did not significantly change following either of the 6 month interventions.

Figure 1
Change in BMD (g/cm²) after weight loss by caloric restriction (WL) and aerobic exercise plus weight loss (AEX+WL) of the a) femoral neck and b) total femur in both African American (AA) and Caucasian (C) women combined and by intervention and race.





Values are means ± SEM. Intervention Effect: †P=0.07. Change from baseline: *P<0.01

There were no race by intervention interactions or race effects following the intervention period; however, there were several intervention effects (10). The AEX+WL group decreased their % body fat by ~1% more than the WL group (P<0.05), and WL resulted in a two-fold greater loss of lean mass than AEX+WL (P<0.01). There was a significant difference between the change in VO2max following both interventions. The AEX+WL group improved their VO2max by 12%, while among women in the WL group, it decreased by 0.5% (intervention effect: P<0.001). WL tended to result in less urinary Ca2+ excretion than AEX+WL (P=0.07). Total caloric intake decreased in both groups (both P<0.01). The change in protein intake was greater for the WL group than the AEX+WL group (P<0.05). Specifically, protein intake increased following WL (P<0.05), but did not significantly change following AEX+WL. No intervention effects were observed for changes in dietary Ca2+ intake. There was a trend for the women undergoing WL to lose 1.5 fold more femoral neck BMD than those involved in AEX+WL (P=0.07). When interventions and races were combined, there were no association between changes in BMD and changes in weight, BMI, lean mass, VO2max, urinary Ca2+ excretion, or dietary intake.

Discussion

Decreases in BMD, leading to an increased risk of osteoporosis and fractures, is a serious health concern for aging women. While the greater prevalence of obesity observed in African Americans is potentially protective to BMD, older, obese African Americans are still at risk, albeit lower than Caucasians, for developing osteoporosis. Therefore, we specifically compared Caucasian and African American women to determine if race affects BMD changes following six months of WL and AEX+WL. Our results indicate that despite beginning the interventions with greater body weight and BMD, African American women lose similar amounts of femoral neck and total femur BMD as Caucasian women following WL and AEX+WL. However, AEX+WL tends to attenuate femoral neck BMD decreases compared to WL alone, regardless of race. This suggests that, similar to Caucasian postmenopausal women, Africa American women would benefit from the addition of aerobic exercise to WL to prevent a decline in femoral neck BMD.

As anticipated, we observed that body weight, BMI, lean mass, and fat mass were greater in African American than Caucasian women at baseline, respectively, and that each body composition measure was associated with baseline BMD after controlling for age and race. As reported by others (13), femoral neck, total femur, and lumbar spine BMD were greater in African Americans than Caucasians. BMD differences may be explained by racial differences in both the formation of BMD, as well as the rate of BMD loss commonly observed with aging. African Americans have greater deposition of bone minerals and, possibly, formation of higher quality bone, including more favorable Ca2+ absorption and retention during growth, lower rate of mineralized matrix apposition, and a longer period of bone formation (14). Following both the WL and AEX+WL interventions, no race main effects were observed for changes in BMD and both groups lost femoral neck BMD. Our data indicate that African American women are not spared from BMD decreases even if they begin the intervention with greater body weight and BMD than Caucasian women. The AEX+WL group tended to lose less femoral neck BMD than the WL group. This suggests the need for postmenopausal women to perform aerobic exercise when following a weight loss regimen.

Racial differences in baseline serum hormones of interest were analyzed to determine their effect on BMD prior to the weight reduction interventions. As reported in our study, previous research indicate that serum concentrations of 25(OH)D, a hormone involved in the mineralization, growth, and remodeling of bone, are typically lower in African American than Caucasian women (15). Vitamin D is found in very few foods, but it is commonly consumed as a dietary supplement and produced endogenously. Not only do African Americans have lower vitamin D intakes from foods and supplements (15), but the increased skin pigmentation in African Americans inhibits cutaneous synthesis of cholecalciferol, the metabolic precursor to 25(OH)D (16). Normal values for serum 25(OH)D range from 20-100 ng/ml, indicating that our group of African American women were on average vitamin D deficient. Although racial differences in IGF-1 has been shown previously (17), we did not observe a differences in IGF-1 in our sample of African American compared to Caucasian women. Women in the current study were within expected ranges for IGF-1 (reference range: 97-292 ng/mL). African American women had slightly elevated PTH concentrations (reference range: 10-55 pg/ml), a factor known to decrease BMD. Other studies also have observed this non-significant elevation of PTH in African Americans (18). Although one limitation of this study was the lack of serum hormone assessment following the interventions, the results are often mixed in this context. For example, Sukumar et al. (19) found that weight loss was associated with a decrease in PTH and IGF-1 and an increase in 25(OH)D in postmenopausal women. In contrast, Ricci et al. (20) found that IGF-1 and 25(OH)D were not affected by weight loss, but weight loss resulted in a significant increase in PTH in postmenopausal women. Both studies enrolled primarily Caucasian women. Therefore, it is evident that further research is needed to examine the impact that race plays on these serum hormones and how WL and AEX+WL affect changes in these hormones. Low serum 25(OH)D and elevated PTH also signify the need to assess dietary intake in older African American women.

Our study does not support a relationship between urinary Ca2+ excretion and BMD in older women. Both African American and Caucasian women excreted urinary Ca2+ concentration within the normal range of 100-300 mg/day. We observed a trend for lower urinary Ca2+ excretion in African Americans than Caucasians, which has been reported previously in both young and older women (21, 22), and may indicate lower bone turnover at baseline despite African Americans having lower vitamin D and a trend for elevated PTH. Our results contradict a previous report of an association between changes in urinary Ca2+ and losses of bone following weight loss in obese women (23). Also, previous reports suggest that chronic aerobic exercise training does not appear to alter Ca2+ excretion in older women (24). In the current study, AEX+WL tended to result in increased urinary Ca2+ excretion, while WL tended to result in less loss of urinary Ca2+. The differences between the current intervention effects and previous data may be explained by differences in dietary intake as urinary Ca2+ excretion is highly dependent upon dietary Ca2+ and protein intake (25).

Baseline dietary intake of protein and Ca2+ were lower in African American than Caucasian women. It is suggested that healthy, ambulatory older adults should consume at least 1.0 g of protein/kg/d (26), which neither race achieved. Sukumar et al. (19) showed that a higher protein diet (24% protein) versus a normal protein diet (18% protein) consumed during weight loss results in attenuated loss of BMD at the hip and spine. Although the WL group increased their protein intake during the interventions, the average protein intake remained below the recommended 1.0 g/kg/d, which may explain the decrease in femoral neck BMD observed with WL when both races were combined. Furthermore, in the current study, both races also consumed less than the recommended intake of 1,200 mg/d of Ca2+ at baseline (27) and intake did not change following either intervention. Ricci et al. [20] found normalization of bone turnover occurs if postmenopausal women supplement with 1,000 mg/d of Ca2+. Additionally, adults who consumed a high dairy Ca2+ diet (2,400 mg) had slower bone turnover than those who consumed less Ca2+ (500 mg) (28). The literature shows that Ca2+ intake is often suboptimal for older Americans, especially African Americans, whether from foods or foods combined with dietary supplement, with fewer than 5% of free living older adults consuming the recommended daily dairy servings (29). Additionally, women report consuming ~50% of their dietary Ca2+ needs through foods, with only 50% consuming additional Ca2+ through supplements (29). These dietary data would suggest that both African American and Caucasian women need to increase dietary intake of protein and Ca2+ to combat bone decreases associated with aging and prior to or during a weight loss program.

In summary, both African American and Caucasian postmenopausal women are susceptible to BMD loss following WL. However, a trend for less reduction in femoral neck BMD following AEX+WL supports the recommendation for performing aerobic exercise during weight loss to attenuate decreases in BMD in both races. Our results suggest that promoting adequate dietary intake of Ca2+ and protein and monitoring urinary Ca2+ excretion prior to and during weight loss with and without aerobic training may be prudent in both African American and Caucasian postmenopausal women.

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Conflict of Interest: All authors have no conflicts of interest.

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