

## Brief report

# Change in Bone Mineral Density During Weight Loss with Resistance Versus Aerobic Exercise Training in Older Adults

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## Abstract

**Background:** To examine the effect of exercise modality during weight loss on hip and spine bone mineral density (BMD) in overweight and obese, older adults.

**Methods:** This analysis compared data from two 5-month, randomized controlled trials of caloric restriction (CR; inducing 5–10% weight loss) with either resistance training (RT) or aerobic training (AT) in overweight and obese, older adults. Participants in the RT + CR study underwent 3 days/week of 8 upper/lower body exercises (3 sets, 10 repetitions at 70% 1 RM) and participants in the AT+CR study underwent 4 days/week of treadmill walking (30 min at 65–70% heart rate reserve). BMD at the total hip, femoral neck, and lumbar spine was assessed via dual-energy X-ray absorptiometry at baseline and 5 months.

**Results:** A total of 123 adults (69.4 ± 3.5 years, 67% female, 81% Caucasian) participated in the RT+CR ( $n = 60$ ) and AT+CR ( $n = 63$ ) interventions. Average weight loss was 5.7% (95% CI: 4.6–6.7%) and 8.2% (95% CI: 7.2–9.3%) in RT+CR and AT+CR groups, respectively. After adjustment for age, gender, race, baseline BMI and BMD, and weight change, differential treatment effects were observed for total hip and femoral neck (both  $p < .05$ ), but not lumbar spine. Total hip (1.83 [–3.90, 7.55] mg/cm<sup>2</sup>) and femoral neck (9.14 [–0.70, 18.98] mg/cm<sup>2</sup>) BMD was unchanged in RT+CR participants, and modestly decreased in AT+CR participants (total hip: –7.01 [–12.73, –1.29] mg/cm<sup>2</sup>; femoral neck: –5.36 [–14.92, 4.20] mg/cm<sup>2</sup>).

**Conclusions:** Results suggest performing resistance, rather than aerobic, training during CR may attenuate loss of hip and femoral neck BMD in overweight and obese older adults. Findings warrant replication from a long-term, adequately powered, RCT.

**Keywords:** Bone aging—Caloric restriction—Exercise—Obesity.

Aging and obesity are prevalent risk factors for morbidity and mortality (1); yet, recommendation of intentional weight loss to treat obesity in older adults remains controversial. In part, this can be attributed to the well documented reduction in bone mineral density (BMD) associated with weight loss and concerns about augmented risk of fracture (2). Performance of regular musculoskeletal loading (ie, resistance) and/or weight-bearing aerobic (ie, walking) exercise has been shown to diminish the loss of BMD during weight loss (3–6); however, this beneficial finding is not universally reported (7–9), and surprisingly the type of exercise most effective for maintaining BMD in older adults during intentional weight loss is unknown.

Such information could be used to maximize the benefit-to-risk ratio of weight loss therapy for obese, older adults.

The purpose of this study is to begin to determine whether resistance training (RT) or weight-bearing aerobic training (AT) is more effective at maintaining BMD in overweight and obese, older adults during caloric restriction (CR) targeting 5–10% weight loss over a 5-month period. Based on meta-analytic data in weight stable older adults suggesting that resistance, rather than aerobic, training is more osteogenic for this population (10,11), we hypothesize that RT will be more effective at maintaining BMD than AT when combined with CR-induced weight loss.

## Materials and Methods

### Study Overview

This study is a retrospective analysis of data collected as part of two 5-month studies of CR with either RT (NCT01049698) or AT (NCT01048736) in overweight and obese (BMI = 27–45 kg/m<sup>2</sup>), older (65–79 years) adults. The first study randomized participants to a structured RT program (3 days/week; 8 upper/lower body exercises, 3 sets, 10 repetitions at 70% 1 repetition maximum) with and without CR. The second study randomized participants to a structured AT program (4 days/week of treadmill walking; 30 minutes at 65–70% heart rate reserve) with and without CR. The present analysis compares RT+CR and AT+CR groups, only.

### Study Participants

Participants in both studies were enrolled on the basis of the following general inclusion and exclusion criteria: (a) aged 65–79 years; (b) sedentary (no purposeful RT or AT in the past 6 months); (c) non-smoking  $\geq 1$  year; (d) weight stable ( $<5\%$  weight change in the past 6 months); and (e) without insulin-dependent diabetes or evidence of clinical depression, cognitive impairment, heart disease, cancer, liver or renal disease, chronic pulmonary disease, uncontrolled hypertension, physical impairment, or any contraindication for exercise or weight loss (ie, physician diagnosed osteoporosis). Notably, BMI inclusion criteria differed by study (BMI range: 27–35 kg/m<sup>2</sup> for RT+CR and 30–45 kg/m<sup>2</sup> for AT+CR).

### Intervention Descriptions

#### RT+CR

Full details of the RT+CR intervention are published (12). Briefly, participants underwent 5 months of supervised RT 3 days/week on weight-stack resistance machines (Cybex International Inc. and Nautilus Inc.). The machines used were (a) leg press, (b) leg extension, (c) seated leg curl, (d) seated calf, (e) incline press, (f) compound row, (g) triceps press, and (h) bicep curl and the maximal weight that a person could lift with the correct form in a single repetition (1RM) was used to prescribe intensity. The training goal was to complete 3 sets of 10 repetitions for each exercise at 70% 1RM for that specific exercise. Resistance was increased when a participant was able to complete 10 repetitions on the third set for 2 consecutive sessions.

The dietary weight-loss intervention was designed to elicit moderate weight loss (5–10%) over the course of the study. Each participant was assigned a daily caloric intake to follow, which was derived from subtracting 600 kcal from his or her estimated daily energy needs for weight maintenance. A maximum of two meal replacements per day (Slim-Fast Inc.) were provided to participants along with a daily calcium (1200 mg/day) and vitamin D (800 IU/day) supplement (Caltrate® 600 + D3).

#### AT+CR

Details of the AT+CR intervention are published (13). Briefly, participants underwent 5 months of supervised treadmill walking 4 days/week for 30 minutes at 65–70% heart rate (HR) reserve. At least two HR readings were taken during each walking session and used to monitor compliance to the prescribed intensity.

The dietary weight-loss intervention was designed to elicit moderate weight loss (5%) over the course of the study. Each participant was assigned a daily caloric intake by subtracting 250 kcal from his or her estimated daily energy needs for weight maintenance. Participants were provided with a controlled diet consisting of 2 meals/day (lunch and supper) prepared by a Clinical Research Metabolic kitchen containing less than 30% calories from fat and at least 0.8 grams of protein per kg of ideal body weight. Participants

prepared their own breakfast from an approved breakfast menu and were provided with a daily calcium (1200 mg/day) and vitamin D (800 IU/day) supplement (Caltrate® 600 + D3).

### Assessments

Participant age, gender, and race/ethnicity were captured via self-report at the baseline assessment visit. All body composition-related variables were collected within 3 weeks prior to the intervention start date and 1 week after intervention close. Height was measured using a Heightronic™ 235 stadiometer (QuickMedical, Issaquah, WA) and body mass was measured using a Detecto 6855 digital scale (Detecto, Webb City, MO), both without shoes and outer garments. BMI was calculated as body mass divided by height squared.

Percent total body fat and areal BMD (g/cm<sup>2</sup>) at the posterior-anterior lumbar spine (L1–L4) and left hip (unless contraindicated and including femoral neck, trochanter, and intertrochanter space) were measured using dual-energy X-ray absorptiometry (DXA, Hologic Delphi A 11.0 QDR, Bedford, MA) at baseline and 5 months. DXA measurements were made by a certified technician blinded to treatment arm and following the manufacturer's recommendations for patient positioning and scanning, with direct machine measures uploaded for analysis. The coefficient of variation for this technique at our center is 1.0% for both the lumbar spine and proximal femur. Osteoporosis and osteopenia were defined using location-specific T-scores  $\leq 2.5$  and between  $-2.5$  and  $-1$ , respectively (14).

### Statistical Analysis

Baseline characteristics were summarized overall and by group using descriptive measures. Comparisons of regional BMD over time and between groups at 5 months were performed using one-way analysis of covariance, including baseline age, gender, race, baseline BMI, baseline BMD, and weight change. Interactions between group and exercise session compliance, and group and gender were tested. All comparisons were performed using SAS v9.4 (SAS Institute, Cary, NC) and inferential measures were deemed significant at a 0.05 level.

## Results

### Baseline Participant Characteristics

Table 1 contains relevant baseline descriptive characteristics of the study samples. In groups combined, participants were

**Table 1.** Baseline Descriptive Characteristics According to Treatment Group

	RT+CR <i>n</i> = 63	AT+CR <i>n</i> = 60
Baseline Characteristics		
Age (years)	70.0 $\pm$ 3.8	68.7 $\pm$ 3.1
Female, <i>n</i> (%)	37 (58.7)	45 (75.0)
White, <i>n</i> (%)	55 (87.3)	45 (75.0)
Body mass (kg)*	85.4 $\pm$ 11.7	92.4 $\pm$ 12.2
BMI (kg/m <sup>2</sup> )*	30.4 $\pm$ 2.2	34.7 $\pm$ 3.7
Body fat (%)	40.2 $\pm$ 6.2	44.6 $\pm$ 6.7
Total hip BMD (g/cm <sup>2</sup> )	0.96 $\pm$ 0.15	0.98 $\pm$ 0.13
Femoral neck BMD (g/cm <sup>2</sup> )	0.77 $\pm$ 0.13	0.78 $\pm$ 0.11
Lumbar spine BMD (g/cm <sup>2</sup> )	1.10 $\pm$ 0.22	1.10 $\pm$ 0.18
Osteopenia at any site, <i>n</i> (%)	36 (57)	29 (48)
Osteoporosis at any site, <i>n</i> (%)	3 (5)	0 (0)

Note: Data are presented as means  $\pm$  SD or *n* (%).

\**p* < .05 between groups.

**Table 2.** Five-Month Treatment Effects on Regional BMD, After Adjustment for Age, Gender, Race, Baseline BMI, Baseline Regional BMD, and Weight Change.

Change in BMD	RT+CR	AT+CR	<i>p</i> for Group*Time
	Mean (95% CI)	Mean (95% CI)	
Total hip (mg/cm <sup>2</sup> )	1.83 (−3.90, 7.55)	−7.01 (−12.73, −1.29)	.02
Femoral neck (mg/cm <sup>2</sup> )	9.14 (−0.70, 18.98)	−5.36 (−14.92, 4.20)	.03
Lumbar spine (mg/cm <sup>2</sup> )	13.01 (2.87, 23.15)	11.06 (0.91, 21.20)	.77

69.4 ± 3.5 years old, 67% were female, and 81% were Caucasian. Three subjects (5%) presented with osteoporosis and 53% with osteopenia (based on a baseline T-scores at the total hip, femoral neck, or lumbar spine). With the exception of BMI and percentage body fat, which were lower in RT+CR (30.4 ± 2.2 kg/m<sup>2</sup>, 40.2 ± 6.2%) compared with AT+CR (34.7 ± 3.7 kg/m<sup>2</sup>, 44.6 ± 6.7%), all other variables were balanced between the groups/studies at baseline (all *p* ≥ .05).

### Intervention Process Measures

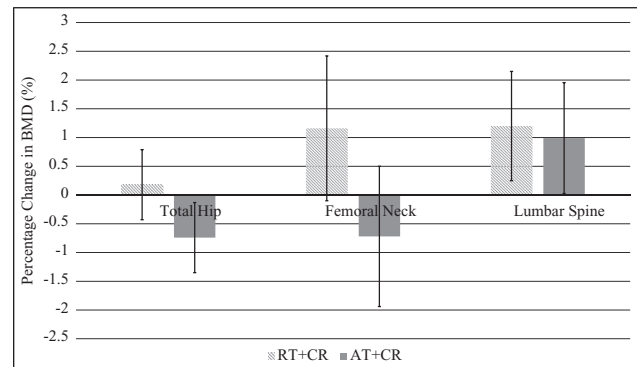
Fifty-three and 57 participants completed the RT+CR and AT+CR interventions, respectively, representing an 84–95% completion rate. Exercise session attendance was 82% for RT+CR and 88% for AT+CR, and overall the majority (79%) of individuals attended at least 80% of group exercise sessions (between group *p* = .10). Average weight loss was 5.7% (4.6–6.7%) and 8.2% (95% CI: 7.2–9.3%) in the RT+CR and AT+CR groups, respectively.

### Intervention Effect on Regional BMD

Adjusted treatment effects on BMD (in mg/cm<sup>2</sup>) are presented in Table 2. Differential treatment effects were observed at the total hip and femoral neck, but not the lumbar spine. Specifically, total hip (1.83 [−3.90, 7.55] mg/cm<sup>2</sup>) and femoral neck (9.14 [−0.70, 18.98] mg/cm<sup>2</sup>) BMD was unchanged in RT+CR participants, and modestly decreased in AT+CR participants (total hip: −7.01 [−12.73, −1.29] mg/cm<sup>2</sup>; femoral neck: −5.36 [−14.92, 4.20] mg/cm<sup>2</sup>). Follow-up lumbar spine BMD was increased above baseline in both RT+CR and AT+CR (13.01 [2.87, 23.15] mg/cm<sup>2</sup> vs 11.06 [0.91, 21.20] mg/cm<sup>2</sup>), but not differently from each other (*p* = .77). Corresponding adjusted percentage change estimates for the total hip, femoral neck and lumbar spine are presented, by group, in Figure 1. Sensitivity analyses testing for interactions between group assignment and exercise session compliance were null (all *p* > .05). No interaction between group and gender was observed for any BMD site; however, because differential loss in BMD is expected in men versus women, gender-stratified treatment effects are presented in Supplementary Table 1.

### Discussion

Exercise is recommended for both prevention and treatment of osteoporosis (15); however, the optimal exercise strategy for preserving bone health—especially during weight loss in old age—is unknown. Results from this study suggest that the addition of RT to CR may better preserve hip BMD as compared to AT added to CR. Because the goal of physical activity for the maintenance of bone health is not necessarily to increase BMD, but to reduce bone loss, our tentative findings may prove clinically meaningful in older individuals and warrant replication from a long-term, randomized controlled trial.

**Figure 1.** Adjusted treatment effects on percentage change in regional BMD. Model-adjusted estimates control for baseline age, gender, race, baseline BMI, baseline regional BMD, and weight change.

A limited number of studies in older adults have been designed to examine whether the inclusion of exercise into a weight loss program can offset the well-known weight loss-associated reductions in BMD, with disparate findings reported (3–8). Data from RCTs of at least 5–6 months in duration indicate high intensity AT+RT (4) or RT alone (3), during weight loss, can attenuate loss of hip BMD, as long as participants remain compliant with the exercise protocol (7). Results from the present study confirm and extend existing knowledge by demonstrating a superior osteoprotective effect of RT compared to AT during CR, potentially due to greater joint-reaction forces associated with RT (14). Pragmatically, if preservation of BMD during weight loss is a primary concern (2), this information may guide geriatricians to recommend RT over RT+AT due to the potential for interference in adaptations to the exercise modalities (16) and reduced compliance when instating multiple behavioral changes (17).

A limitation of this analysis is the quasi-experimental design where participants from two different randomized controlled trials were compared. Although study populations were similar and we adjusted for several known confounders (including baseline BMI and achieved weight loss), results may be influenced selection bias or other influential covariates that may differ by group (ie, dietary composition). A second limitation is the short study duration; bone remodeling is a slow process, requiring a minimum of 4–6 months and may continue for 1–2 years (18). Thus, the signal we observed in the relatively short time period may not reflect long-term differences between groups. Lastly, the lack of a differential treatment effect at the lumbar spine may call into question the robustness of our findings; however, the spine region is notorious for measurement error (especially in the context of obesity and weight loss (2), and noted by the relatively large confidence intervals in our dataset as compared to the total hip), with weight loss-associated reductions in BMD more consistently observed at the total hip region (19). That being said, because both groups increased lumbar spine BMD, it also may

signal that either RT or AT is appropriate to counter weight loss-associated bone loss at that site.

Despite these limitations, direct comparison of RT and AT during CR in older adults is novel and descriptive data presented here is informative. The field would benefit from results from a long term, RCT specifically designed to test the effect of exercise modality during weight loss on bone health in older adults. Additional incorporation of bone quality metrics (including bone strength, microarchitecture, and turnover) and fall-risk assessment would enhance the clinical utility of future research endeavors, as fracture is ultimately the main outcome of interest.

## Supplementary Material

Supplementary material is available at *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* online.

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