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Weight-bearing, aerobic exercise increases markers of bone formation during short-term weight loss in overweight and obese men and women

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Abstract

We investigated the impact of weight-bearing, aerobic exercise– and diet-induced weight loss on markers of bone turnover during a larger study of changes in metabolic fitness during short-term weight reduction using a repeated-measures, within-subject experimental design. Subjects (N = 19) underwent 6 weeks of energy restriction (reduced by ~3140 kJ/d) and aerobic exercise (~1675 kJ/d, walking or jogging at 60% maximum oxygen consumption) to induce a 5% reduction in body weight. Bone turnover markers and hormones were measured in serum collected at baseline and after 6 weeks of weight loss. Despite a 5% reduction in body weight at week 6, markers of bone formation, osteocalcin, and bone alkaline phosphatase, were significantly increased, and resorption markers, C-terminal cross-links of type I collagen and soluble receptor activator of nuclear factor κB ligand, were unchanged after 6 weeks of energy restriction and exercise. The concentration of leptin was significantly reduced after weight loss, but insulinlike growth factor I (IGF-I) and cortisol levels were unaffected. In conclusion, weight-bearing, aerobic exercise training may favorably affect the balance between bone resorption and formation during weight loss.

1. Introduction

Loss of bone mineral density is a negative consequence of diet-induced weight loss (reviewed in reference [1]) and is associated with increased serum markers of bone turnover in pre- and postmenopausal obese women [2-7] and adult men and women [8]. Short-term energy restriction, in the absence of weight loss, also adversely affects markers of bone formation and resorption in humans [9] and experimental animals [10,11]. Weight-bearing exercise is osteogenic and is a nonpharmacologic tool for the prevention and amelioration of osteoporosis (reviewed in references [12,13]). Therefore, we investigated the impact of weight-bearing, aerobic exercise– and diet-induced weight loss on markers of bone turnover during a larger study of changes in metabolic fitness during short-term weight reduction.

2. Methods

Thirteen women and 6 men, aged 18 to 44 years, were recruited for this study. Participants were overweight to class I obese, sedentary, nonsmokers, and weight stable. All procedures involving human subjects were in accordance with the ethical standards of the University of Missouri Institutional Review Board and with the Helsinki Declaration of 1975 as revised in 1983.

Subjects followed a 6-week intervention of energy restriction (reduced by ~3140 kJ/d) and weight-bearing exercise (~1675 kJ/d) that was designed to produce a 5% reduction in body weight. The exercise training consisted of brisk walking and/or slow jogging on a treadmill 5 d/wk at approximately 60% of measured maximum oxygen consumption (75% maximal heart rate), 45 min/d [14]. Dietary intake was assessed by using written food diaries (Food Processor 8.0, esha, Salem, OR).

Body mass index (BMI, in kilograms per meter squared) was determined from measurements of body weight and height; body composition was assessed by 3-site skinfold measurement. Blood was collected before and after weight loss between 0700 and 0800 after a 12-hour fast and a 48-hour no-exercise control period, during the follicular phase of the menstrual cycle. Serum was separated by centrifugation and stored at −80°C. Serum concentrations of soluble receptor activator of nuclear factor κB ligand

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Table 1
Effects of 6 weeks of short-term weight loss on anthropometrics, aerobic capacity, nutrient intake, hormones, and bone turnover markers

	Baseline	Week 6	% Change
Anthropometrics			
Body weight (kg)	81.3 ± 2.8	77.3 ± 2.6*	−4.9
BMI (kg/m^2)	28.9 ± 0.7	27.5 ± 0.6*	−4.8
Body fat (%)	36.7 ± 2.0	33.6 ± 2.0*	−8.4
VO_2max (L/min)	2.7 ± 0.1	2.9 ± 0.2*	7.4
Nutrient intake[a]			
Energy (kJ/d)	10,058 ± 410	6284 ± 201*	−37.5
Calcium (mg/d)	965.6 ± 94.4	712.3 ± 65.0*	−26.3
Hormones			
Cortisol (μg/dL)	43.9 ± 3.5	43.3 ± 2.4	−1.3
IGF-I (ng/mL)	151.8 ± 11.2	145.6 ± 9.5	−4.1
Leptin (ng/mL)	41.1 ± 3.9	29.4 ± 4.2*	−28.5
Bone turnover markers			
OC (ng/mL)	5.4 ± 0.8	6.4 ± 1.0*	18.5
BAP (U/L)	21.1 ± 1.1	22.3 ± 1.1*	5.7
OPG (pg/mL)	98 ± 4	94 ± 6	4.1
sRANKL (pg/mL)	5.9 ± 1.6	5.4 ± 1.7	−8.5
CTX (ng/mL)	0.53 ± 0.06	0.56 ± 0.07	5.6

Values are means ± SE. N = 19 for all variables, with the exception of sRANKL (above detection limit for n = 7). Conversion factor to SI units: cortisol, 27.59 (nmol/L). VO_2max indicates maximum oxygen consumption.

[a] There were no significant changes in other micronutrients from baseline to week 6.

* $P < .05$, significant difference from baseline.

(sRANKL), osteocalcin (OC), osteoprotegerin (OPG; ALPCO Diagnostics, Windham, NH), bone alkaline phosphatase (BAP; Quidel, San Diego, CA), C-terminal cross-links of type I collagen (CTX; Nordic Bioscience, Denmark), total insulinlike growth factor I (IGF-I), leptin, and cortisol (DS Labs, Webster, TX) were measured by commercially available enzyme-linked immunosorbent assays in duplicate (intra-assay coefficients of variation, <8%).

2.1. Statistics

Means were analyzed by using 1-way analysis of variance with repeated-measures (SPSS/11.0, SPSS, Chicago, IL). A 2-way analysis of variance was used to test for significant main effects of sex and time, as well as a sex by time interaction. Sex by time interactions were not significant, so the results are presented for both sexes combined. The threshold for significance was set at P less than .05.

3. Results

Body weight, BMI, and percent body fat significantly decreased as a result of the diet and exercise intervention (Table 1). Daily energy and calcium intakes were significantly lower after 6 weeks of the weight loss intervention (Table 1). The concentration of leptin in serum significantly decreased; cortisol and IGF-I levels were unchanged (Table 1). Serum BAP and OC levels significantly increased from before to after weight loss; OPG, sRANKL, and CTX levels did not change (Table 1).

4. Discussion

In the current study, serum markers of bone formation, OC and BAP, were significantly increased (18.5% and 5.7%, respectively) after 6 weeks of weight-bearing, aerobic exercise and energy restriction, resulting in a 5% reduction in body weight, in sedentary, overweight, and obese young adults. Moreover, serum markers of bone resorption, CTX and sRANKL, were unchanged as a result of the diet and exercise intervention. It is notable that we observed favorable changes in bone formation and resorption markers despite a significant decrease in calcium intake from approximately 1000 to approximately 700 mg/d. Weight loss of approximately 10%, achieved by 6 months of energy restriction, typically increases levels of urinary markers of bone resorption by 30% to 50% and of serum markers of bone formation to a lesser extent, 3% to 18% [2,3,5,8], resulting in a significant reduction in bone mineral density [2-4]. The deleterious effects of energy restriction on bone turnover are ameliorated by increasing calcium intake to 1.6 to 1.8 g/d [2-5]. In light of these findings, the results of the current study suggest that adding weight-bearing, aerobic exercise to the weight loss intervention favorably affects the balance between bone resorption and formation.

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