

Effect of Weighted Exercises on Bone Mineral Density in Post Menopausal Women

A Systematic Review

Carol Hamilton Zehnacker, PT, DPT, MS;¹ Anita Bemis-Dougherty, PT, DPT, MAS²

¹ Physical Therapy Consults, Frederick, MD

² The American Physical Therapy Association, Alexandria, VA

ABSTRACT

Purpose: Osteoporosis is both preventable and treatable with exercise playing an important role in osteogenesis. The purpose of this systematic review was to determine which specific exercise programs utilizing weights were effective in maintaining or increasing bone mineral density (BMD) in postmenopausal women. **Methods:** A computerized search of the MEDLINE, CINAHL, EMBASE, PEDro, and Science Citation databases was conducted for the period 1990 through February 2005. The search was performed using English language-only keyword searches using MESH terms *osteoporosis*, *postmenopausal*, *exercise*, *weight training*, and *bone mineral density*. A total of 20 articles was critically evaluated for the quality of an intervention study using the criteria developed by MacDermid. An expert on the topic was asked to review the list of articles for omissions. **Results:** The review revealed evidence to support the effectiveness of weight training exercises to increase BMD in postmenopausal women. The increases in BMD were site-specific and required high loading with a training intensity of 70% to 90% of 1 RM for 8 to 12 repetitions of 2 to 3 sets performed over one year duration. **Conclusion:** Weighted exercises can help in maintaining BMD in postmenopausal women and increasing BMD of the spine and hip in women with osteopenia and osteoporosis. The exercise program must be incorporated into a lifestyle change and be lifelong due to the chronic nature of bone loss in older women.

Key Words: osteoporosis, weighted exercise, postmenopausal women, bone mineral density

INTRODUCTION

Osteoporosis, a degenerative disease, is a systemic skeletal disease characterized by low bone mass and micro-architectural deterioration of bone tissue that results in increased fragility and risk of fracture.^{1,2} The bones of individuals with osteopenia demonstrate, on radiograph, decreased mineral content, with a bone mineral density (BMD) that is lower than normal but less

than the threshold for osteoporosis.² Osteoporosis is a major public health concern and the prevention of osteoporosis is a national health initiative from the Surgeon General's office. In 2004, there were an estimated 10.1 million people aged 50 and older in the United States with osteoporosis, and 33.6 million people with osteopenic low bone mass placing them at risk for osteoporosis and fractures.³ The Surgeon General predicts that, by 2020, there will be 13.9 million individuals with osteoporosis (more than 75% of these will be women) and 47.5 million with low bone mass (64% women).³ The World Health Organization reports 30% of postmenopausal females have osteoporosis.^{4,5}

Postmenopausal or Type I osteoporosis develops when circulating estrogen levels decrease after menopause, leading to an increased rate of bone resorption without a concomitant increase in bone formation. This contributes to an acceleration of bone loss.⁶ Type I osteoporosis usually affects women within 15 to 20 years of menopause with the most rapid bone loss occurring about 5 to 7 years following menopause.⁷ The most common osteoporosis-related fracture sites are at the hip, vertebral bodies, and wrist.⁵

Type II osteoporosis, seen in both genders of older adults is a gradual decrease in BMD that affects both cortical and trabecular bone and is associated with hip fractures.⁹ A decrease in the bone formation phase results as the bone is resorbed, creating a cavity of normal depth while less new bone is formed to completely fill in the cavity.¹⁰

Aging, when combined with deconditioning and disease, is associated with gait and balance problems that increase the risk for falls and subsequent osteoporotic fractures. Approximately 300,000 hip fractures occur each year in the United States with an associated cost of over \$9 billion.⁸ Hip, vertebral, and shoulder fractures have a high mortality rate when compared with the general population; mortality is more significant immediately after the fracture compared with 5 years later.¹²

Bone mineral density, the amount of hydroxyapatite relative to the area of bone, is measured by dual energy x-ray absorptiometry (DXA scan). Bone mineral density is used to estimate the risk of fracture and determine whether a patient has osteopenia or osteoporosis. The World Health Organization established the criteria for calculating the T-score with the BMD reference range of women in their thirties at peak bone mass as normal. A BMD of 1.0 to 2.5 standard deviations (SD) below the reference range is classified as osteopenia and a BMD of greater than 2.5 SD below the reference range is classified as osteoporosis.¹ As a rule, for every SD below the reference range the risk of fracture

Address all correspondence to: Carol Hamilton Zehnacker, Physical Therapy Consults, 7918 River Run Court, Frederick, MD 21701, Ph: 301-695-4648 (doctorcz@comcast.net).

doubles.¹ Reducing the risk for osteoporosis involves increasing bone mass at skeletal maturity and preventing or slowing the loss of BMD with advancing age.¹³

Hormone replacement therapy (HRT), calcitonin, bisphosphonates, and selective estrogen receptor modulators (SERM) are pharmacological agents used to prevent or treat osteoporosis.¹⁴ These medications are expensive and may have serious side effects. Lifestyle changes with adequate intake of calcium, cessation of smoking, moderation in alcohol consumption, resistance exercise and weight-bearing/loading exercise may be better alternatives or adjuncts to drug therapy.

According to Wolff's law, the remodeling of bone occurs in response to physical stresses.¹⁵ Recent studies on animal and cell cultures suggest that there is a direct correlation between physical loading and bone formation and that muscular activity is effective in maintaining BMD if the forces developed reach a minimal effective strain.¹⁶ The osteogenic stimulus provided by load-bearing exercise indicates it is an important lifestyle factor that can be used for the prevention of bone loss.⁷

Although considerable literature relating to the role of exercise and its positive effects on BMD exists, questions remain regarding the specific exercise prescription necessary to reduce the risks or effects of osteoporosis in the postmenopausal woman. Physical therapy interventions discussed in the literature have focused on postural awareness, balance training, and aerobic exercises to decrease the risk factors and consequences associated with osteoporosis. While a body of evidence that indicates that weighted exercises increase and maintain BMD is present, it has not been previously consolidated for the benefit of physical therapists. The purpose of this systematic review is to evaluate the research concerning the effectiveness of weighted exercise on BMD addressing postmenopausal women at risk or with osteoporosis.

METHODS

The search strategy was based on the method described by Sackett et al.¹⁷ A computerized literature review of the MEDLINE, CINAHL, EMBASE, PEDro, and Science Citation databases was conducted for the period 1990 through February 2005. The search was performed using English language-only keyword searches using the MESH terms *osteoporosis*, *exercise*, *weight training*, *postmenopausal women*, and *bone mineral density*. A search using the term *osteoporosis* yielded 32,275 articles. Adding *exercise* to the search resulted in 1,464 articles. Further combining *bone mineral density* narrowed the list to 691 articles. The addition of *postmenopausal women* reduced the number of articles to 179. The addition of *weight training* reduced the number of articles to 20.

Articles were eligible for inclusion in the analysis if they: (1) were randomized controlled trials or nonrandomized trials with more than 15 participants, (2) had less than a 35% drop out rate, (3) enrolled postmenopausal women between the ages of 40 to 80 years old, (4) employed DXA scan as the method of determining BMD, and (5) incorporated weighted or resistive exercises as a therapeutic intervention to promote osteogenesis. Articles were excluded from analysis if subjects: (1) had any orthopedic problem (including a BMD result of -3 SD or below and a history of an osteoporotic fracture) or

cardiovascular problem that would limit resistive exercise, or (2) took any medication known to alter bone metabolism except estrogen, or (3) if the article was a review of the literature rather than a study evaluating efficacy of an intervention.

The 20 articles were critically evaluated for the quality of an intervention study using the criteria developed by MacDermid.¹⁸ The MacDermid guidelines include a quality rating of 24 measures for each study based on a 0, 1, 2 score where 0 is the lowest and 2 is the highest score.

RESULTS

We concluded from the 20 articles reviewed that evidence was present to support that weighted exercises increased BMD in postmenopausal women. Table 1 provides a synopsis of the articles that were reviewed. An increase in the BMD was found in 7 studies.^{1,19-24} A positive outcome included bone maintenance in the exercise group as compared with the decline of BMD in the control group.^{11,25-28,42} Both ground reaction forces and joint reaction forces resulted in increases in BMD.²⁰ Sites exposed to both ground reaction forces and joint reaction forces improved more than sites stressed only by ground reaction forces.^{1,11} When studies allowed HRT and segregated the users into groups, those groups with a combination of HRT and exercise produced greater increases in BMD than either treatment alone.²⁹ No difference in BMD in the exercise group and the control group was noted in 3 studies.³⁰⁻³²

Duration

All of the studies that had a positive outcome or showed an increase in BMD were over 11 months duration.^{1,19-22,26,27,29,33} Three studies with interventions lasting 4 to 8 months had a result of less bone loss in the exercise group as compared to the control group.^{23,25,28,42} One study had an increase of lumbar BMD with the duration of a weighted exercise program lasting 9 months.²⁴

Training intensity and frequency

Of the studies with positive results, the training intensity was 70% to 90% of 1 RM (maximal load for one repetition with good form) for 2 to 3 sets of 8 to 12 repetitions.^{1,19-22,25-27,29,33,42} Training sessions were performed 3 to 5 times a week and lasted from 45 minutes to 70 minutes a session.^{1,20-22,26,27,29,42} Bone mineral density of the lumbar spine was increased when weights equaling 80% of maximal back extensor strength were used.³⁴

Site-specific training effects

Site-specific positive exercise effect in BMD was noted in the femoral trochanter.^{11,20-22,29,33} Increase or maintenance in BMD was found at the femoral neck.^{11,19,20,22,28} A positive exercise effect was reported at Ward's triangle.^{20,22,29} A positive exercise effect on BMD was noted in the lumbar spine.^{19,20,22,24} Only 1 study reported a positive exercise effect on the wrist – ultradistal radial site.²²

Specific Exercises

Four types of exercises increased the BMD, including: (1) weighted squats, hack squats, leg press, hip extension, hip adduction, hip abduction, knee extension, and hamstring

curls;^{1,11,19-22,26-29,33,42} (2) stair-climbing/step boxes with weighted vest, jumping exercises with weighted vests, power cleans with weighted vests and beverage boxes;^{1,11,26,29} (3) military press, latissimus pull down, seated rowing, and rotary torso;^{1,19-21,25,29,42}

(4) back extension exercises with weighted backpacks,³⁴ leg press, bench press, and trunk extension;²⁴ and elbow flexion, wrist curl, reverse wrist curl, triceps extension, forearm pronation, and supination.^{22, 27}

Table 1. Characteristics of Selected Studies of the Effectiveness of Weighted Exercise on Bone Mineral Density for Postmenopausal Women

Publication	Quality Score	Sample Size (n)	Age (yrs) Range or mean	HRT	Exercise Duration (months)	Training intensity, and frequency	Specific exercises used	DXA Specifics	Results
Ryan et al (1998) ¹³	20	27	62 ± 1	No	4	90% RM with weight increased so 12 – 15 repetitions per exercise were achieved. 1 hour sessions 3 x week	Leg press, chest press, leg curl, latissimus pull down, elbow flexion, elbow extension, leg extension, upper back row, military press, hip abductor, hip adductor, and abdominal curls using Inshape equipment, Keiser K-300 machines, and Cybex equipment.	lumbar spine L ₂ – L ₄ , femoral neck & greater trochanter, Ward's Triangle	90% compliance. BMD did not significantly change, but were maintained. This maintenance of BMD is clinically significant because of the rate of BMD loss with advancing age.
Kerr et al (2001) ³³	37	126	60 ± 5	No	12	3 one-hour sessions per week.	30 minutes of resistance weight training; 3 sets of 8 RM and increased their load Fitness group: stationary bicycle at moderate intensity (heart rate < 150 beats per minute)	intertrochanteric region, Ward's triangle, radial forearm every 6 months	71% retention at 2 years. No difference between the groups at the forearm, lumbar spine, or whole body sites. There was a significant effect of the strength program group for the BMD total body and intertrochanteric hip site.
Adami et al (1999) ³¹	39	250 125 EG 125 CG	52-72	No	6	2 sessions per week but were encouraged to repeat exercises at home for 30 minutes per day.	Warm up exercises, 70 minutes of exercises to maximize stress on the wrist (press up, flexion in prone, playing volleyball either sitting or standing), 10 minutes of lifting a 500-g weight with the forearm in a partially supinated position, weight liftings rose from 10 to 25.	Lumbar spine, femoral neck, ultradistal & proximal radius pQCT –cortical component of ultradistal radius	Site-specific moderate exercises have little effect on bone mass. Relevant changes can be obtained with exercise programs that produce stress to the skeleton
Going et al (2003) ¹	40	320	HRT EG. 54.8 ± 4 HRT CG 54.9 ± 5 No HRT EG 55.8 ± 4.7 No HRT CG 57.1 ± 5	HRT 159 Non-HRT 161	12	3 x week: 70 – 80% 1 RM Intensity maintained at 60% of maximal heart rate.	Stretching, balance and aerobic weight bearing activity for warm up, weight lifting (free weights and machines including leg press, hack squats or Smith squats, lat pull-downs, lateral rows, back extensions, right & left dumbbell presses, and rotary torso – 2 sets of 6 – 8 repetitions at 70% or 80% 1RM), an additional weight bearing circuit of moderate impact activities, stair climbing/step boxes with weighted vests.	lumbar spine L ₂ – L ₄ , femoral neck & trochanter, total body	Overall 83% (n=266) of the baseline sample completed 1-year assessments. Regional BMD can be improved with resistance exercise combined with aerobic, weight bearing activity at clinically relevant sites in postmenopausal women. Sites exposed to ground-reaction forces and joint reaction forces generally improved more than sites stressed by only ground reaction forces.

Table 1. Continued.

Publication	Quality Score	Sample Size (n)	Age (yrs) Range or mean	HRT	Exercise Duration (months)	Training intensity, and frequency	Specific exercises used	DXA Specifics	Results
Kemmler et al (2004) ³⁹	38	83 50 EG 33 CG	48 -68	No	26	2 sessions of 60 – 70 minutes at gym & 2 sessions of 25 minutes per week at home. First 3 months at 2 sets of 20 reps at 50% 1 RM then 2 sets of 15 reps at 60% 1RM. After 5 months 2 sets of 12 reps at 65% 1 RM. After 7 months 12 weeks of high intensity at 70-90% 1RM interweaved by 4-5 week period of low intensity of 50% 1RM.	13 exercises affecting all main muscle groups in TechnoGym- wide bench press, 1-arm dumbbell, rowing, squats/power cleans with weighted vests and beverage boxes : Home exercises– isometrics, belt, and stretching exercises, rope skipping program after 20 weeks.	lumbar spine L ₁ -L ₄ proximal femur, forearm QCT L ₁ -L ₃ of trabecular & cortical regions of interest	DXA of lumbar spine showed a 2.3% decrease in the CG. BMD in the EG was stable. In proximal femur, CG had a decrease of 2.9% - small but significant loss in EG. At forearm site, significant loss of BMD in both EG and CG.
Snow et al (2000) ¹¹	27	18 9 EG, 9 CG	64.1 ± 1.6	2 EG 2 CG	60	3 x week	Lower body resistance and jumping exercises with weighted vests	right proximal femur, femoral neck & trochanter, total hip	After 5 years of participation in weighted vest plus jump training, BMD at the femoral neck, trochanter, and total hip was maintained. In the controls, BMD decreased by 3.2% - 4.4% at those regions.
Kerr et al (1996) ²²	39	56	46-55	No	12	Strength training 3 sets X 8RM – one side EG, other side CG, endurance training 3 sets X 8RM for 3 sessions/week.	Strength – biceps curl, wrist curl, reverse wrist curl, triceps extension, forearm pronation and supination. Leg press, hip abduction, hip adduction, flexion, extension, and hamstrings	femoral neck & trochanter, intertrochanter, radial forearm every 3 mos	80% compliance with strength; 87% compliance with endurance; Significant increase in BMD for exercising the limb at the trochanteric hip site, intertrochanteric hip site, and Ward's triangle and at the ultradistal radial site.
Cussler et al (2003) ²¹	39	140	46 -66	50% using HRT	12	2 sets of 6 - 8 reps at 70% - 80% 1 RM. 3 sessions/ week of 65 – 70 minutes	Stretching, balance and aerobic weight bearing activity for warm-up; weight lifting, an additional weight bearing circuit of moderate impact activities, stair climbing/step boxes with weighted vests, leg press, lat pull down, weighted march, seated row, back extension, one arm dumbbell press, military press, Smith back squats, rotary torso.	lumbar spine L ₂ -L ₄ , femoral neck & trochanter, total body	Significant BMD change in femoral trochanter with weighted squats, military press, lat pull down, seated rowing, rotary torso, seated leg press. Weighted march had marginal effect and back extension had little effect on femoral trochanteric BMD. Femoral neck and lumbar spine BMD changes were not significant. Total body DXA was statistically significant with weighted marching exercises.

Table 1. Continued.

Publication	Quality Score	Sample Size (n)	Age (yrs) Range or mean	HRT	Exercise Duration (months)	Training intensity, and frequency	Specific exercises used	DXA Specifics	Results
Kohrt et al (1997) ²⁰	37	39: 14 GRF 12 JRF 13 CG	60 -74	No for the last 2 years	11	3 -5 sessions/ week GRF - 85% maximal heart rate JRF - 2 -3 sets of 8 - 12 reps to fatigue 2 x week.	GRF - 45 min daily of walking, stair climbing, or jogging at 80-85% heart rate JRF - Overhead press, biceps curl, triceps extension, leg press, leg extension, leg flexion, bench press, squats, ½ session of rowing at 80 - 85% heart rate	proximal femur, femoral neck, & trochanter, Ward's triangle; lumbar spine L ₂ -L ₄ ; wrist, total body performed every 3 months	Both exercise groups (GRF and JRF) resulted in significant increases in BMD of the whole body, lumbar spine, and Ward's triangle region of the proximal femur. Significant increase in BMD of the femoral neck in response to the GRF program, but not the JRF program.
Bassey et al (1995) ³²	38	44; 20 EG 24 CG	50 - 60	No	12	Daily home exercise and weekly exercise classes	EG: did 50 'heel drops' daily and a workout on rebounders with some jumping and skipping. CG: did flexibility exercises at home and a class of low-impact exercise and some arm work.	lumbar spine L ₂ -L ₃ nondominant proximal femur, distal radius.	No significant increases in BMD at any site were found in the exercise or control group. There was a fall in BMD at the ultradistal radius in the exercise group.
Nelson et al (1994) ¹⁹	40	39 20 EG 19 CG	50 -70	No	12	2 x week for 45 minutes 80% 1RM 3 sets of 8 reps for 6-9 seconds with 3 second rest between reps 16 on Borg scale for back extension and abdominal	Double leg press, knee extension, lateral pull-down, back extension, abdominal flexion machines	lumbar spine L ₂ -L ₄ , femoral neck, total body	BMD of femoral neck increased 0.9% ± 4.5% in EG and decreased 2.5% ± 3.8% in CG Lumbar spine BMD increased by 1.0% ± 3.6% in EG and decreased by -1.8% ± 3.5% in CG Total body BMD preserved at 0,0% ± 3.0% in EG and decreased -1.2% ± 3.4% in CG
Bemben et al (2000) ⁴²	37	25 HL- 10 HR - 7 CG -8	41-60	No	6	3 x week HL - 80% 1RM 3 sets of 8 reps HR- 40 % 1 RM 3 sets of 16 reps	Knee extension, knee flexion, leg press, shoulder press, biceps curl, triceps extension, seated row, latissimus pull down, hip flexion, adduction, abduction, and extension	total body lumbar spine L ₂ -L ₄ proximal femur, femoral neck & trochanter, Ward's triangle, total hip	No significant change in BMD although the maintenance of bone may be clinically significant when the early postmenopausal phase can be as much as a 5% loss per yr.
Smidt et al (1991) ³⁰	38	49 22EG 27CG	CG 55.4± 8 CG EG 56.6± 6.6	9 CG 8 EG	12	3 x week 3 sets of 10 reps 70% intensity	Sit-ups, prone trunk extension, double leg flexion	lumbar spine L ₂ -L ₄ femoral neck & trochanter, Ward's triangle	No significant difference in CG and EG
Rhodes et al (2000) ²⁷	42	44 22 EG 22 CG	65 -75	No	12	3 x week 1 hr. session 75 % of 1RM 3 sets of 8 reps	Chest press, leg press, biceps curl, triceps extension, quad extension, hamstring curl	lumbar spine femoral neck & trochanter, Ward's triangle	Although there were no statistically significant changes, the trend indicated an increase in the BMD for the EG and a decrease in BMD for the CG
Hartard et al (1996) ²⁸	35	31 16 EG 15 CG	EG 63.6 ± 6.2 CG 67.4± 9.7	No	6	2 x week 70% of 1 RM 1 set of 8-12 reps	Pec deck, inverted pecs, shoulder adduction and abduction, hip flexion, extension, adduction, abduction, leg press, back extension, abdominal strengthening	lumbar spine L ₂ -L ₄ left femoral neck	Differences in lumbar spine were not significant. No change in femoral neck for EG but significant decrease in CG

Table 1. Continued.

Publication	Quality Score	Sample Size (n)	Age (yrs) Range or mean	HRT	Exercise Duration (months)	Training intensity, and frequency	Specific exercises used	DXA Specifics	Results
Milliken et al (2003) ²⁹	39	94 EG /no HRT 17 CG/no HRT- 21 EG// HRT 17 CG HRT 21	40-65	Yes	12	3 x week 75 minute sessions 2 sets of 6-8 reps 70-80% 1 RM	20 mins of weight bearing activity with weighted vest 50 –70% max heart rate resistance exercises- leg press, squat, seated one armed dumbbell press, back extension, rotary torso, seated rows, lateral pull downs postural exercises of scapular stabilization and abdominals	lumbar spine right proximal femur performed at 6 months and 12 months	HRT increased BMD at most sites and the combination of HRT and exercises produced increases in BMD greater than either treatment alone
Jessup et al (2003) ²³	45	18 9 EG 9 CG	69.2 ± 3.5	No	8	3 x week 60 - 90 minute sessions	8 – 10 reps at 75% 1RM. Used a weighted vest that was 10% of the participant's body weight for walking, stair climbing, and balance-training exercises.	left hip and lumbar spine performed at initial entry into the study and within 3 -5 days of the end of the 32 weeks.	Significant loss of femoral neck BMD in the CG. Improvements in BMD of the femoral neck and lumbar spine, and body sway, strength, and body weight in the EG.
Kemmler et al (2005) ²⁶	39	78 48 EG 30 CG	48-60	No	36	2 sessions of 60-70 minutes at gym 2 sessions of 25 minutes at home per week.	13 exercises affecting all main muscle groups	lumbar spine L ₁ -L ₄ femoral neck & trochanter, ultradistal radius	Stabilization of BMD in spine, neck and trochanter in the EG and decrease in CG BMD at forearm decreased by 4% in both groups
Sinaki et al (2002) ³⁴	34	65 34 EG 31 CG	55.6 48-65	No	24	1 x day 5 x week	Progressive, resistive eight-lifting exercise program for back extensor muscles using a backpack with weights equal to 30% of maximal back extensor strength – lifting 10 times in prone position. Both EG and CG were instructed in proper lifting and good posture. Strength & activity level were recorded a each 4- wk visit	lumbar spine L ₂ -L ₄	Incidence of vertebral compression was 4.3% in the CG and 11.6% in the EG. The relative risk for compression fracture was 2.7 times greater in the CG than the EG. At 2 yrs follow-up BMD of lumbar spine was not significantly different however it decreased significantly in 10 yrs.
Maddalozzo et al (2000) ³⁵	35	54 28 men 26 women 27 HI 27 MI	54.58 ± 3.2 men 52.83±3.26 women	No	9	3 x week 75 minutes sessions MI 3 sets of 10-13 reps at 40-60% RM HI 3 sets of 8 reps at 70% RM	MI- leg extension, leg press, hamstring curls, arm curl, triceps press, chest press, pec deck, shoulder press, side lateral raise, lat pull down, seated row, abdominal crunch, calf raise HI- free weight back squat, dead lift, biceps curl, sit-ups, triceps extension, chest press, shoulder press, lat pull down, leg curl, gripper, calf raise	proximal femoral neck & greater trochanter, Ward's triangle, lumbar spine L ₂ -L ₄ whole body baseline performed at 12 weeks and 36 weeks	High intensity promoted bone gain in the spine and trochanter of older men and at the trochanter n older women
Pruitt et al (1992) ²⁴	40	26: 17 EG 9 CG	EG 53.6 CG 55.6	No	9	1 hour sessions initially 50% - 60% of 1 RM but increased so only 10 RM were possible	Biceps curl, lat pull down, bench press, wrist roller, leg press, leg abduction leg adduction, leg curl, leg extension, trunk extension, hip extension, lateral flexion	right femur & lumbar spine L ₂ -L ₄	Mean change in BMD for the weighted exercise group (1.6 ± 1.2%) was significantly different from the control group (-3.6 ± 1.5%). EG showed a positive effect on vertebral BMD.

Key : EG = Exercise Group, CG = Control Group, HRT = Hormone Replacement Therapy, RM = Repetition Maximum, reps = Repetitions, GRF = Ground Reaction Forces, JRF = Joint Reaction Forces, HL = High Load, HR = High Repetitions, HI = High Intensity, MI = Moderate Intensity

DISCUSSION

This systematic review provides evidence that weighted exercise can slow the rate of loss or increase BMD in postmenopausal women, primarily in the femoral trochanter and to a lesser extent in femoral neck and lumbar spine. Osteogenesis occurs in this population when particular criteria for exercise are met.

Duration/Training Length

From an analysis of the studies in this review we conclude that the duration of the exercise should be at least one year for changes to be noted in BMD at the femoral neck and trochanter. Bone is a dynamic tissue that undergoes a never-ceasing process of formation and resorption and responds to the constantly changing mechanical forces impinging on its surfaces.²⁸ Duration is important because the total time of bone formation at a bone multicellular unit is 4 to 6 months long and some bone may be in the resorption phase when BMD is measured at 6 months.⁴² Weight training should last at least 2 to 3 times that period (12 to 18 months) to ensure the training effect on BMD could be measured in an equilibrium state.³⁰

According to Bassey et al, postmenopausal women have different BMD responses to high impact exercise than premenopausal women.⁴¹ Premenopausal women significantly increased their BMD in response to the training exercise while postmenopausal women did not. Snow et al attribute this to postmenopausal women requiring longer periods of intervention and higher loads because they are in a period of accelerated bone loss.¹¹

Adami et al reported that a 6 month long exercise program resulted in no significant change in the BMD of the femoral neck, lumbar spine, and ultra-distal and proximal radius; but they did note an increase in the density of the cortical component of the ultra-distal radius.³¹ Since the distal radius is a smaller bone than the femur, bone turnover will require less time; the higher percentage of cortical bone of the femoral neck likely needs additional remodeling time.³⁵

Researchers have shown that training effects were likely to disappear after the training was discontinued as BMD decreased after the completion of the exercise.^{28,34,36} Sinaki et al report that 8 years after cessation of the 2-year exercise program, the back exercise group had a loss in BMD but the loss in BMD was significantly less in the back exercise group than in the control group.³⁴

Since these exercise-induced adaptations are reversible, it is important for individuals to remain physically active throughout their entire lifespan.⁹ Postmenopausal women should maintain a lifestyle with regular exercise to prevent osteoporosis and osteoporotic fractures in later years.²³

The results of this review suggest that physical therapists should revise their usual treatment protocols for postmenopausal women with osteopenia or those women who are at risk for osteoporosis. Women who are postmenopausal with osteopenia would likely benefit from a less frequent but longer period of intervention, with an emphasis on monitoring and adjustment of the exercise prescription to make effective changes in increasing bone mass or preventing bone loss. The resistance or training load should be adjusted to 70% to 90%

of 1 RM. Dividing the exercise protocol into periods (periodization) with structured macrocycles and mesocycles interweaves high intensity training with regeneration periods to avoid injury and provide motivation.²⁶

Training Intensity

Weight training provides an efficient way to load the clinically important sites at the spine, hip, and wrist with the benefits of improving muscular strength and balance, which decreases the risk for falls.²⁴ Smith and Gilligan concluded that increased cellular activity found in cell and organ culture research presented the likelihood of proportional reactions of bone to loading.¹⁴ If a load is detected as being greater than the load threshold, there will be an increase in internal strain and bone formation will occur.²² To show a significant impact on bone density, the exercise intensity (strain magnitude) must be higher than the minimum effective strain threshold of bone.²⁵

Kerr et al concluded that the peak load is more important than the number of loading cycles in increasing bone mass in early postmenopausal women.²² Their study demonstrated that the skeleton adapts to the increasing load applied by progressive resistance training in postmenopausal women by increasing BMD.²² Nelson et al concluded that high intensity (80% of 1RM) strength training had a positive effect on the femoral neck BMD and lumbar BMD as well as promoting increased muscle mass, strength, dynamic balance, and overall physical activity level in postmenopausal women.¹⁹ Maddalozzo et al noted that high intensity weight training (70% - 90% of 1RM in a 25-week periodization program) promoted an increase in BMD at the spine and trochanter in older men and at the trochanter in older women.³⁵ The majority of the studies demonstrated that the traditional high intensity strength training program (70% to 90% of 1RM) had an osteogenic effect on the BMD in postmenopausal women by either increasing or preventing further bone loss as compared to the control group.^{1,19-21,23, 25-29,42}

Training frequency/session length

Another variable of the exercise prescription that impacts the BMD is the sessions per week and the length of time per session. Although the load was rigorous (total of 90 high intensity trunk muscle contractions three times per week) and the duration was a year, Smidt et al employed a session duration (15 -20 minutes) that was considerably less than the studies that affected BMD positively.³⁰ Other studies that reported limited effect on BMD were limited to 2 sessions per week and 1 session per week.^{31,32}

Site-specific training effect

The skeleton has 2 main extrinsic forces acting on it during exercise to produce an increase in BMD: (1) supporting body mass against gravity, and (2) the musculo-tendinous unit pulling on the bone during muscular contraction.⁹ Since increasing muscle strength was correlated with an increase in bone mass at several hip sites, it would suggest that the mechanism by which osteogenesis occurred is by muscle pull on the attached site of muscle insertion.^{1,21,22} Kerr et al reported proportional effects were site specific with larger osteogenic outcomes at

the femoral trochanter (site of the gluteus minimus, gluteus medius, and piriformis), but not at the femoral neck when high levels of loading were compared with low levels of loading in strength training among postmenopausal women.²² Kerr et al also found an increase in BMD at the intertrochanter site (which includes the lesser trochanter where the psoas and iliacus muscles insert) and Ward's triangle.²² Nelson et al's results were an exception in that they noted an increase BMD in the femoral neck.¹⁹ Other studies used weighted exercise with ground force reaction and demonstrated a positive exercise effect on all regions of the hip.^{1,11,23} Cussler et al used resistive training with the weighted vest and aerobic weight bearing activity which resulted in an increased BMD at the femoral trochanter.²¹ Although loading occurred at both the femoral trochanter and femoral neck sites, muscle attachments are found on the femoral trochanter and not on the femoral neck and the transmission of impact forces may not be as effective in stimulating bone growth at the femoral neck.²¹ Kohrt et al reported significant increases in BMD of the lumbar spine, Ward's triangle, and proximal femur with both ground force reaction and joint force reaction groups but only noted significant increase in the femoral neck with the ground force reaction group.²⁰

Of the other studies that reported BMD gains or stabilization in the lumbar spine, 2 studies involved exercises with muscle attachments site specific to the lumbar spine.^{19, 24} One study involved the use of ground forces with use of a weighted vest for walking and stair climbing,²³ and another study employed both.²⁶ Only one study was found to have a positive exercise effect in increasing BMD at the wrist and that involved muscle contraction.²²

Site-specific exercises

Bone mineral density is related to the strength of the anatomically related structures.²⁵ Weighted squats produced the largest effect on the femoral trochanter.²¹ The squat is an exercise that uses body weight in addition to the external load lifted and it is unlikely that few other lower extremity weight lifting exercises generate similar magnitudes of force.²⁰ Significant correlation of BMD gains in the femoral trochanter with percent increase in weight lifted was reported for the seated leg press.^{21,22,25} Increases in BMD at the femoral trochanteric and intertrochanteric regions were associated with high intensity resistive exercises involving hip flexion, abduction and extension, and knee extension and flexion. These exercises were site specific to the femoral trochanter and suggests that this area is sensitive to muscle pull or joint reaction forces to increase BMD.²² Bembien et al also reported positive correlations between hip BMD sites (femoral neck, Ward's triangle, trochanter, and total hip) and hip strength (abduction, extension, and flexion) and leg strength (leg press and hamstring curls).⁴² An unexpected finding of Cussler et al was the association of femoral trochanter change in BMD with the military press and it was speculated that with the absence of direct muscle targeting at the hip site, substantial loading occurred directly above the hip region in this exercise to produce an osteogenic response.²¹ Ryan et al noted high correlation between leg press strength and L₂-L₄ BMD, femo-

ral neck BMD, Ward's triangle BMD, and the greater trochanter BMD. In addition strong correlation was found between chest press strength and L₂-L₄ BMD, femoral neck BMD, Ward's triangle BMD, and greater trochanter BMD.¹³ Exercises utilizing gravitational forces or ground reaction forces as stair climbing, walking, or jumping with weighted vests are effective in stimulating bone formation in the L₂-L₄ and the femoral neck.^{11,20,23}

Safety of Weighted Interventions

Injuries were rarely reported in any of the studies reviewed; this could be because injuries failed to occur or that injuries were not reported. One woman left the Erlangen Fitness Osteoporosis Prevention Study Program because of a hairline fracture of the os pubis after a fall in the aerobic sequence.²⁶ Excluding postmenopausal women with a BMD of greater than -3.0 for whom high intensity exercise is contraindicated was a safety feature built into the studies to prevent osteoporotic fractures from occurring during the intervention. Women with severe osteoporosis are still cautioned to avoid any exercise that would: (1) jar the spine, such as high impact sports - jogging, high impact aerobics; (2) involve spinal flexion - sit-ups, toe-touches, rowing machines; (3) increase the risk of falling such as skating, skiing, trampolines; and (4) involve hip abduction-adduction movements.³⁸

Older adults tolerated high intensity weight training well.³⁵ Hartard et al reported that the results of their study showed that in addition to the effect on BMD, a considerable increase in muscle strength can be achieved by strength training at 70% RM without adverse effects on hemodynamics and metabolism.²⁸ Snow et al concluded that their 5-year program of weight training augmented by the use of the weighted vest with jumping is safe, practical, and promotes both adherence and compliance in older women.¹¹

Limitations of the Review

A limitation of this review is the inclusion of nonrandomized clinical trials. Kelley reported a trend for nonrandomized trials to yield more positive results than randomized trials, suggesting that nonrandomized trials tend to overestimate the bone response.⁴⁰ Several authors point to the difficulty of randomizing exercise trials. Unlike placebo-controlled pharmaceutical studies, exercise studies cannot be blinded.³⁹ In order to ensure compliance to the exercise-training program, subjects were allowed to choose their groups (exercise group or control group) based on their anticipated compliance.³⁷ Smidt et al allude to the lack of self-assignment as a possible reason for negative outcome of their study.³⁰ They reason that the control group in their study was very physically active; most were disappointed in not being assigned to the exercise group and may have been motivated to maintain high physical activity levels.

Another limitation of this review is the diversity of subjects studied in the same groups and the resulting confounding variables. The studies reviewed had very different inclusion and exclusion criteria. Women who were sedentary whose BMD would respond more readily to an increase in exercise and women who were athletic were in the same groups. Some studies included women taking HRT.^{1,11,21,29,30} Regulation of cal-

cium and vitamin D were required in some studies and not in others. Some studies consisted of women in early menopause, who were in a period of rapid bone loss, in groups with women well beyond menopause whose bone loss was more stable.

More randomized controlled studies are recommended to determine the long-term effects of weighted exercise on BMD for the postmenopausal woman. While many studies are present on the effects of exercise on BMD of the hip, there is a paucity of information on the effects on exercise on the spine and wrist. Future studies should be focused, be free of confounding variables, and limit the influence of HRT and other medications that effect BMD. Groups should also be homogeneous and not have women in the early postmenopausal years mixed in with elderly women.

CONCLUSIONS

The studies included in this review provide evidence to support the use of weighted exercise to increase BMD in postmenopausal women, in order to prevent or reduce the effects of osteoporosis. Therapeutic exercise programs should be site-specific for the hip, spine, and wrist; which are the areas most frequently affected in patients with osteoporosis. The exercise protocol should include sufficient intensity (75% - 80% 1RM, with 8-12 repetitions, for 2 to 3 sets) of joint force reactions and ground force reactions to influence bone formation through muscle contractions and gravitational or loading forces. Exercise sessions should be performed 3 to 5 times per week for at least 45 minutes, and be incorporated into long-standing lifestyle change. Physical therapists can play an important role in prevention and in helping postmenopausal women make lifestyle changes by incorporating periodization to avoid injuries and motivate their patients.

REFERENCES

1. Going S, Lohman T, Houtkooper L, et al. Effects of exercises on bone mineral density in calcium-replete postmenopausal women with and without hormone replacement therapy. *Osteoporosis Int.* 2003;14:637-643.
2. Brown JP, Josse RG. Clinical practice guidelines for the diagnosis and management of osteoporosis in Canada. *Can Med Assoc J.* 2002;167:1-34.
3. Surgeon General's Report on bone health and osteoporosis. October 2004: Available at: www.surgeongeneral.gov/library/bonehealth/docs/exec_summ.pdf. Accessed February 28, 2005.
4. Kanis JA, WHO Study Group. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: Synopsis of a WHO report. *Osteoporosis Int.* 1994;4:368-381.
5. National Osteoporosis Foundation. *Physician's Guide to Prevention and Treatment of Osteoporosis*. Washington, DC; 1999.
6. Riggs BL, Wahner HW, Dunn WL, et al. Differential changes in bone mineral density of the appendicular and axial skeleton with aging. *J Clin Invest.* 1991;67:328-355.
7. Bemben DA, Fetters N. The independent and additive effects of exercise training and estrogen on bone metabolism. *J Strength Cond Res.* 2000;14:114-120.
8. Cooper C, Fogelman K, Melton LJ II. Bisphosphonates and vertebral fracture: an epidemiological perspective. *Osteoporosis Int.* 1991;2:1-4.
9. Bemben DA. Exercise interventions for osteoporosis prevention in postmenopausal women. *J Okla State Med Assoc.* 1999;92:66-70.
10. Edward BJ, Perry HM. Age-related osteoporosis. *Clin Geriatr Med.* 1994;10:575-588.
11. Snow CM, Shaw JM, Winters KM, Witzke KA. Long-term exercise using weighted vests prevents hip bone loss in postmenopausal women. *J Geronto A Biol Sci Med Sci.* 2000;55:M489-M491.
12. Johnell O. Mortality after osteoporotic fractures. *Osteoporosis Int.* 2004;15:38-42.
13. Ryan AS, Treuth MS, Hunter GR, Elahi D, Hurlbut DE. Resistive training maintains bone density in postmenopausal women. *Calcif Tissue Int.* 1998;62:295-299.
14. Smith E, Gilligan C. Dose response relationship between physical loading and mechanical competence of bone. *Bone.* 1996;18:45S-50S.
15. Salter RB. *Textbook of Disorder and Injuries of the Musculoskeletal System*. 2nd ed. Baltimore, Md: Williams & Wilkins; 1983.
16. Conley MS, Rozenek R. National Strength and Conditioning Association Position Statement; Health Aspects of Resistance Exercise and Training. *Strength and Condition J.* 2001;23:9-23.
17. Sackett DL, Straus SE, Richardson WS, et al. *Evidence-Based Medicine: How to Practice and Teach EBM*. 2nd ed. Edinburgh, UK: Churchill Livingstone; 2000.
18. MacDermid J. An introduction to evidence-based practice for hand therapists. *J Hand Ther.* 2004;17:105-117.
19. Nelson ME, Fiatarone MA, Moganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. *JAMA.* 1994;272:1909-1914.
20. Kohrt WM, Ehsani AA, Birge SJ, et al. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. *J Bone Miner Res.* 1997;12:1253-1261.
21. Cussler EC, Lohman TG, Going SB, et al. Weight lifted strength training predicts bone change in postmenopausal women. *Med Sci Sports Exerc.* 2003;10:10-17.
22. Kerr D, Morton A, Dick I, et al. Exercise effects on bone mass in postmenopausal women are site specific and load-dependent. *J Bone Miner Res.* 1996;11:218-225.
23. Jessup JV, Horne C, Vishen RK, et al. Effects of exercise on bone density, balance, and self-efficacy in older women. *Biol Res Nurs.* 2003;4:171-180.
24. Pruitt LA, Jackson RD, Bartels RL, Lenhard HJ. Weight-training effects on bone mineral density in early postmenopausal women. *J Bone Miner Res.* 1992;7:179-185.
25. Ryan AS, Ivey FM, Hurlbut DE, et al. Regional bone mineral density after resistive training in young and older men and women. *Scand J Med Sci Sports.* 2004;14:16-23.
26. Kemmler W, von Stengel S, Weineck J, Lauber D, Kaslender W, Engelke K. Exercise effects on menopausal risk factors of early postmenopausal women: 3-yr Erlangen fitness

- osteoporosis prevention study results. *Med Sci Sports Exerc.* 2005;37:194-203.
27. Rhodes EC, Martin AD. Effects of one year of resistance training on the relation between muscular strength and bone density in elderly women. *Br J Sports Med.* 2000;34:18-22.
 28. Hartard M, Haber P, Ilieva D, et al. Systematic strength training as a model of therapeutic intervention. A controlled trial in postmenopausal women with osteopenia. *Am J Phys Med Rehabil.* 1996;75:21-28.
 29. Milliken LA, Going SB, Houtkooper LB, et al. Effects of exercise training on bone remodeling, insulin-like growth factors, and bone mineral density in postmenopausal women with and without hormone replacement therapy. *Calcif Tissue Int.* 2003;72:478-484.
 30. Smidt GL, Lin S, O'Dwyer KD, et al. The effect of high-intensity trunk exercise on bone mineral density of postmenopausal women. *Spine.* 1992;17:280-285.
 31. Adami S, Gatti D, Braga V, et al. Site-specific effects of strength training on bone structure and geometry of ultradistal radius in postmenopausal women. *J Bone Miner Res.* 1999;14:120-124.
 32. Bassey EJ, Ramsdale SJ. Weight-bearing exercise and ground reaction forces: a 12-month randomized controlled trial of effects on bone mineral density in healthy postmenopausal women. *Bone.* 1995;16:469-476.
 33. Kerr D, Ackland T. Resistance training over 2 years increases bone mass in calcium-replete postmenopausal women. *J Bone Miner Res.* 2001;16:175-181.
 34. Sinaki M, Itol E, Wahner HW, et al. Stronger back muscles reduce the incidence of vertebral fractures: a prospective 10 year follow-up of postmenopausal women. *Bone.* 2002;30:836-841.
 35. Maddalozzo GF, Snow CM. High intensity resistance training: Effects on bone in older men and women. *Calcif Tissue Int.* 2000;66:339-404.
 36. Dalsky GP, Stocke KS, Ehsani AA, et. al. Weight-bearing exercise training and lumbar bone mineral content in postmenopausal women. *Ann Intern Med.* 1988;108:824-828.
 37. Chien MY, Wu YT, Hsu AT, et. al. Efficacy of a 24-week aerobic exercise program for osteopenic postmenopausal women. *Calcif Tissue Int.* 2000;67:443-448.
 38. Bonnick SL. *The Osteoporosis Handbook.* Dallas, Tex: Taylor Publishing Company; 1994.
 39. Kemmler W, Lauber D, Weineck J, et. al. Benefits of 2 years of intense exercise on bone density, physical fitness, and blood lipids in early postmenopausal osteopenic women. *Arch Intern Med.* 2004;164:1084-1091.
 40. Kelley G. Exercise and regional bone mineral density in postmenopausal women. *Am J Phys Med Rehabil.* 1998;77:76-87.
 41. Bassey EJ, Rothwell MC, Littlewood JJ, Pye DW. Pre- and postmenopausal women have different bone mineral density responses to the same high impact exercises. *J Bone Miner Res.* 1998;13:1805-1815.
 42. Bembien DA, Feters NL, Bembien MG, Nabavi N, Koh ET. Musculoskeletal responses to high and low intensity resistance training in early postmenopausal women. *Med Sci Sports Exerc.* 2000;32:1949-1957.

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