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Designing Exercise Programs to Lower Fracture Risk in Mature Women

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summary

This article reviews recent research on exercise and bone health and, on that basis, develops an effective and safe exercise program for increasing bone strength and reducing fracture risk in mature women with osteoporosis and osteopenia.

Osteoporosis is a disease characterized by low bone mass, deterioration of the architectural strength of bone tissue, and increased risk of bone fracture (9). The World Health Organization defines osteoporosis as bone density that is 2.5 standard deviations or more below that of healthy young adult women. Osteopenia has the same characteristics, although bone deterioration is less advanced; it is diagnosed when bone density is 1–2.5 standard deviations below normal. In Europe, Japan, and the United States, osteoporosis is becoming epidemic. In white women over the age of 50 in the United States, it is estimated that 13–18% have osteoporosis and 37–50% have osteopenia (8).

Because of the increasing use of bone density screening, many women learn they have osteoporosis or osteopenia and high fracture risk before they have irreversible damage such as compression fractures in the spine (3). A number of books (5, 14) provide exercise advice for unfit or frail women with low bone mineral density (BMD), but there is less guidance for more vigorous women who can follow a challenging exercise program that will have the most positive impact on bone health. This article reviews recent research on exercise, bone density, and fracture risk, and then uses research findings to design an exercise program for mature women with poor bone health.

Bone Density And Exercise

Many diverse protocols are used in exercise and BMD research, making it challenging to compare outcomes. Despite this limitation, the following research findings can be used as guidelines for designing exercise programs to lower fracture risk.

Site Specificity

Bones strengthen when the muscles attached to them become stronger. The 1-year Bone Estrogen Strength Training Study (4) included strength training 3 times/wk. The most significant positive effect for hip-bone strength was from weighted squats. Weighted marching showed the most significant correlation (11% increase) between total load and total body BMD. Individuals who play racquet sports have higher BMD in the racquet arm (22).

Specific sites respond differently to exercise stimulus. Two studies used overall body routines to stimulate the hip and spine (10, 18) and reported 1.3 and 1.6% increases in spine BMD at 9 and 12 months, with no increase in hip BMD. Another study reported significant increases in hip BMD only after 18 months, with significant increases in spine BMD at 5 months (13).

Intensity

Relatively high force loading is necessary to increase BMD. In a meta-analysis, Wolff (24) reported that exercise-training programs prevented or reversed an average of 1% bone loss per year. The positive effect of exercise was nearly twice as large when women chose to be in the exercise group. Wolff theorized that women who were more enthusiastic about their training worked more intensely and had better results. Wolff concluded that strength-training programs that failed to improve BMD did not apply the unusual strain distributions and high strain rates required for measurable increases. In studies where no change in BMD was found (2, 7, 17, 18), researchers concluded that exercisers did not train to muscle fatigue or with adequate loads for increased bone mineralization.

Frequency, Recovery, Load, and Sets

High-load, low-repetition exercise routines with adequate recovery time build BMD most effectively. In animal studies, Turner (22) found that bone rapidly becomes desensitized to prolonged exercise and mineralization is enhanced by frequent rest periods between brief intense skeletal-loading sessions. Rats who jumped 100 times a day had no greater BMD improvement than those that jumped 40 times. Rats given 24 hours of rest between sessions had superior bone formation to those given 0–8 hours of rest.

In postmenopausal women, Cussler (4) found that maximal load stimulates BMD increases, not load frequency. Women were instructed to exercise 3 d/wk for 1 year (with 2 sets of 6–8 repetitions with loads at 70–80% 1 repetition maximum [1RM]). Exercise attendance averaged twice per week. Exercises focused on muscle groups with attachments on or near BMD measurement sites and included a squat variation, seated leg press, pull-down, weighted march, seated row, back extension, 1-arm dumbbell press, and the rotary torso machine. Cussler reported that fewer loading cycles were most effective for increasing BMD, and there were diminishing returns with more.

Two other studies explored the association of load and exercise intensity to BMD increases. Kerr (12) reported that strength groups (8 repetitions at 8RM) increased BMD by 2% in most hip sites within 1 year, whereas endurance exercisers (20 repetitions at 20RM) showed no change. Vincent (23) reported that the strength group (8 repetitions at 80% 1RM) increased hip BMD by 2% in 6 months, but endurance exercisers (13 repetitions at 50% 1RM) had no change in BMD.

There was no correlation between number of sets used in studies and increases in BMD. Six studies used 3 sets: 3 (12, 13, 15) reported significant increases in BMD, but 3 (2, 7, 17) reported no change. Three studies used 2 sets: 2 (4, 11) reported improvements in BMD, and 1 (18) reported no change. Two studies (19, 23) used 1 set, and both reported significant improvements.

Progression

Progressive increases in load stimulate increases in muscle and bone strength (4, 12, 18, 20). For example, using 5 resistance exercises—hip extension, knee extension, lateral pull-down, back extension, and abdominal flexion (3 sets of 8 repetitions at 80% 1RM)—twice per week for 1 year, Nelson (15) reported femoral neck BMD increases of +1% versus controls –2.5%. Lumbar spine increases were similar with +1% in the exercise group versus –1.8% in controls. This study increased the load each training session as tolerated for each muscle group.

High-impact Exercise

High-impact exercise builds strong bones. Gymnasts have higher bone density than other athletes because of high-impact exercises, strength, and intense muscle pull (21). In nonathletes, high-impact exercise increased hip BMD by 2–5% in women under 30 who did 50 vertical jumps daily compared with controls who did similar exercise programs that excluded jumping (1). In early postmenopausal women with osteopenia (11), exercisers began rope skipping and closed-leg jumping after 5 months of lower-impact exercise training. After 26 months, the exercise group showed no change in hip BMD, whereas the control group lost about 2%. The exercise group gained approximately 1% BMD in the lumbar spine versus a loss of over 2% in the control group.

Delayed Response

It can take 6 months or more for bone to remodel under the best conditions, and measurable effects of exercise may only be apparent years later. In a 2-year study of women aged 58–75 (20), 27 exercisers practiced 10 back lifts 5 d/wk, progressing to a maximal weight of 50 lb in specially constructed backpacks. After 2 years, there was no change in BMD for controls or exercisers despite large changes in back erector strength in the exercise group. Exercise was discontinued. In a follow-up 10 years later, the exercise group had significantly higher spine BMD, and the relative fracture risk in the spine was 2.7 times greater in the control group than the exercise group.

Bone Mineral Density versus Fracture Risk

Weight-bearing and bone-loading exercise significantly lowers fracture risk even with little or no change in BMD. Although walking does not significantly improve measurable BMD in mature women, in the Nurse's Health Study (6) women who walked 8 h/wk at a moderate pace had 55% fewer hip fractures than sedentary women, and those who walked just 4 h/wk had 41% lower risk.

In animal studies, Turner (22) applied a mechanical load to the right ulna of female rats 3 times/wk for 16 weeks. This load increased the BMD by a modest 5.4% but resulted in a 64% increase in the maximum force the bone could support before breaking. Turner concluded that barely measurable BMD changes dramatically increase bone strength.

Exercise is more osteogenic during skeletal growth than during maturity, al-

Table 1
Beginning-Level Strength Training Routines

Gym routine	Home free-weight routine
Equipment: machines and free weights	**Equipment: adjustable plate dumbbells including 1.25 lb plates**
1. Sit-back squat or leg press	1. Sit-back squat (Figure 1)
2. Leg curl	2. Bridge (Figure 2)
3. Hip-back machine if available	3. Dumbbell overhead press
4. Dumbbell overhead press	4. One-arm dumbbell row
5. Lat pull-down	5. Wall press (Figure 3)
6. Chest press machine (or seated dip)	6. Upward row
7. Row machine	7. Back erector lift (Figure 4)
8. Back erector machine	8. Side bend
9. Side bend (or torso twist)	9. Sit back for abdominals
10. Abdominal machine	10. Wrist curls, both directions
11. Wrist curls, both directions	11. Calf raises

Table 2
Balance Exercises

1. Toe walk. Walk on toes with erect body and chest up. Begin along a wall so you can catch yourself.
2. One-leg stand. Stand next to a chair back or counter, lightly holding the support. Lift 1 leg and hold for a count of 10. Change legs and do the other side. You will find you are better able to balance on 1 leg than the other. Can you do this without holding on? If you need to hold on, keep practicing until you can hold this to a count of 30. Then, begin experimenting with standing on 1 leg without holding on.
3. One-leg stand with knee bend. Use 1 leg and slowly bend the weight-bearing leg. Work up to repeating the bend 10 times on each side (Figure 5).
4. Grapevine walk. Stand so you have space to move to the right. Take a step out to the side with the right (R) foot. Cross left (L) foot over R and shift weight into L foot. Take a second step to the R with R foot and cross L foot behind R. Repeat until you run out of space. Increase difficulty by increasing speed, but not at the expense of maintaining balance.
5. One-leg stand with arm swing. Lift 1 leg off floor and swing arms in gait pattern. Begin by lifting foot just a few inches and swinging arms slightly. Progress by lifting foot higher and increasing arm movement.
6. One-leg stand with eyes closed. First, get balanced on 1 leg, then close eyes, keeping arms poised to support you.

Note: From Daniels (5).

though it reduces fracture risk at any age. According to Turner (22), exercise is only moderately effective at building BMD in older adults, but it is extremely effective at reducing fracture risk. Exercise reshapes bone microstructure and geometry, increasing bone strength and decreasing fracture risk in ways not measurable by bone scan.

In summary, current research on the relationship between exercise and bone health suggests that effective routines must be site specific, high load and/or high impact, progressive, and provide adequate recovery time between challenging exercise sessions. Research also shows that exercise improves bone health and lowers fracture risk in ways not measurable by bone scan. These principles will now be applied to design an exercise routine to lower fracture risk in mature women.

Practical Applications of Research Findings

Many women with osteoporosis or osteopenia have low levels of strength and aerobic fitness. Begin these clients with as few as 3 brief exercise sessions each week, including strength training, balance, and weight-bearing aerobic exercise. The goal is 4–5 bone-stimulating exercise sessions weekly, but health professionals should customize exercise programs as low exercise tolerance and slow recovery are common in older people, especially if they are in poor health.

Strength Training and Balance

In initial strength training sessions, the personal trainer should focus on teaching form and technique so that the client feels competent and safe practicing the routine. Begin with as few as 4 strength exercises using 5–6 repetitions with a light load, including a squat variation, a press, a pull, and an abdominal exercise (Table 1). Balance exercises should also be included (5, 16) as they lessen the fear and danger of falling (Table 2). Clients can practice a brief strength and balance routine 2–3 times/wk, adding 1–2 repetitions per session until they can complete 2 sets of 8 repetitions. Then, rather than adding more sets or repetitions, the client increases the load in small increments as tolerated by each muscle group. When a short routine is mastered, gradually add more exercises until the client is practicing a full routine.

Weight-bearing Aerobics

On alternate days, the client can combine aerobic exercise and bone stimulation by walking with a load. This allows recovery from strength training, adds variety, and provides a different stimulus to bone. For sedentary clients, begin with 10- to 15-minute walks at a com-

Figure 1. Sit-back squat.

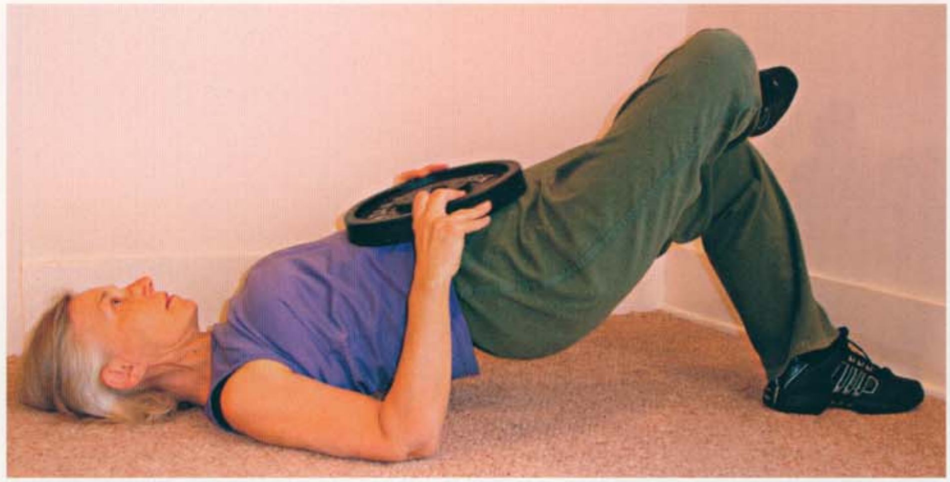

Figure 2. Bridge (progressing by using only 1 leg and holding weight).

fortable pace. Add 5 minutes every week until the client is walking 30 minutes per session. Then gradually increase intensity in the middle 10–15 minutes of the walk, maintaining a pace where she is breathing hard but can still talk. Finally, increase bone loading by progressively adding weight in a backpack or weighted vest.

High-impact Exercise

High-impact exercise provides excellent bone stimulation for women with osteopenia if they have strong muscles and joints. Women who have successfully followed a progressive strength, balance, and weight-bearing aerobic program for at least 5 months may add high-impact exercise to their routine, such as closed-leg jumping, landing with flexed knees on the ball of the foot (11). Women with osteoporosis or those with compromised joints should stimulate bones with higher loads, rather than higher impact, to avoid injury.

Selecting Exercises for Site Specificity

If women wish to exercise at home, they only need a set of adjustable plate dumbbells. Sets with 1.25-lb plates are best for increasing load in small increments.

A sample home routine includes a sit-back squat (Figure 1), bridge (Figure 2), overhead press, 1-arm dumbbell row, wall press (Figure 3) or push-up from knee, upward row, back erector lift (Figure 4), side bend, abdominal sit back, wrist curls in both directions, and a calf raise (Table 1). The bridge variation used is similar to a Pilates or yoga bridge, not a wrestler's bridge. The bridge may not provide adequate challenge for a relatively fit client, so substitute a dumbbell deadlift for the bridge when the client is able. This routine focuses on compound functional exercises that help with balance and daily tasks and provides stimulation to spine, hips, and arms.

The following gym routine also provides appropriate site-specific stimulation: sit-back squat (or other weighted squat variation or leg press), leg curl, hip/back machine, overhead press, lat pull-down, chest press (or seated dip), row, back erector machine, side bend, abdominal machine, and wrist curl in both directions. Encourage clients to practice a weighted squat variation, rather than a leg press, because squatting provides greater load for hips and spine (4).

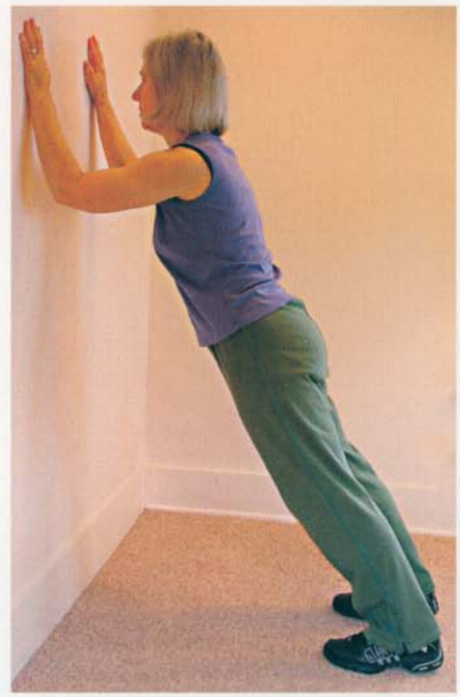

Figure 3. Wall press.

Load and Progression

Training with small loads with many repetitions increases muscle endurance, whereas heavy loading with fewer repetitions is most effective for increasing bone strength. Focus on progressively increasing load and perceived level of exertion, rather than adding large numbers of repetitions or sets. For bone health, 2 sets of 8 repetitions with a progressive load should be effective.

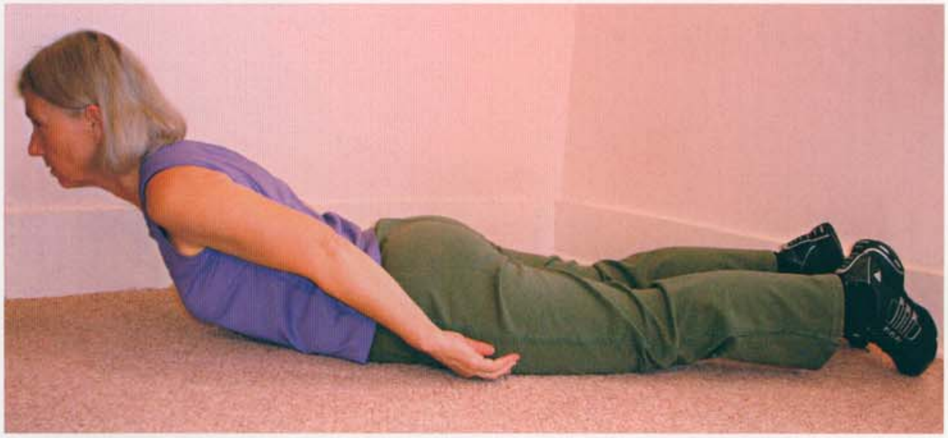

Figure 4. Back lift for back erectors.

Figure 5. One-leg stand with knee bend.

There are many ways to make exercises progressive in a home strength routine. For example, have the client begin with a body weight sit-back squat. When this is no longer challenging, have her wear a well-designed backpack or weighted vest to progressively increase load, beginning with just a few pounds. Another option is to start with a wall press, then have the client progress to a press off of a low counter, and finally move to a push-up from the knee or even a full-body push-up. As long as a client is increasing load in exercises that strengthen the hips, trunk, and arms, she is lowering her fracture risk. By encouraging clients to progress at their own pace, the trainer can acclimate each individual gradually to higher-intensity levels and working to form failure.

Safety and Effective Form

Clients with low bone density or other health risks need an exercise prescription from their doctor. It is the personal trainer's responsibility to keep clients safe, so focus on excellent exercise form with emphasis on back safety where clients with osteoporosis are especially vulnerable. Lower repetition ranges and higher loads make good form challenging but essential. The back should be flat or slightly arched with the shoulders down, scapula pulled together, and the chest lifted. Any exercise is stopped at form failure when the back cannot hold this safe position or the movement becomes unbalanced, asymmetrical, or cannot be completed with full range of motion. Teach a slow, controlled cadence of 4–6 s/repetition. Avoid exercises that require a forward curve of the spine, such as abdominal crunches, since this position makes a weak spine vulnerable to fracture (5).

Emphasize a full range of motion, especially when working the muscles along the back. The last few inches of a pulling motion make all the difference in stimulating the muscles along the spine such as the rhomboid, middle and inferior trapezius, and latissimus dorsi.

Conclusions

Using exercise to improve bone strength brings us back to the basics of training for muscle strength with mature clients. High-load routines that stimulate muscle development in the hips, back, and arms build bone strength in those vulnerable areas. If form is excellent, the routine will be safe for all except those with severe osteoporosis. Finally, a well-designed strength-training program of adequate intensity will dramatically lower lifetime fracture risk, even without measurable increases in BMD. When it comes to bones, reduced fracture risk is the desired result. ♦

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