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Spine Update

Weight-bearing exercise (walking and jogging) play an important role in aerobic conditioning, but have only a modest benefit in the prevention and treatment of osteoporosis. Site-specific resistive exercises appear to have a more consistent benefit on bone mineralization and muscle strength.

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Spine Update
Exercise for Osteoporosis—Is Walking Enough?
The Case For Site Specificity and Resistive Exercise

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Historic and clinical references obtained by general literature review and a Medlars search from 1984—1994 on the impact of muscle strengthening on bone mineralization were reviewed and analyzed. The efficacy of site-specific resistive exercise on bone mineral enhancement and/or preservation as a supplement to weight-bearing exercise is documented.

Previous reports demonstrated that resistive exercises enhance bone mineralization and play an equivalent, or perhaps greater role, than weight-bearing activities in the management of osteoporosis. [Key words: bone mineral densitometry, osteoporosis, resistive and weight-bearing exercise] Spine 1996;21:2809—2813

Although it is generally thought that weight-bearing exercises such as walking have a beneficial effect on bone mineralization, there are a number of studies that challenge this view.[1,3,4,6,10,34,17,24]

There is, however, compelling evidence in animal experiments that resistive exercises maintain or increase bone mineral density in a site-specific manner.[4,6,24] A variety of high-intensity resistive stimuli in avian and mammalian species (mice, rats, dogs, pigs, and horses) were used in these studies.[1,4,6,24] These studies also demonstrated that higher loads at specific sites provided a more effective osteogenic stimulus than generally distributed loading at lower intensity.[6] This finding is of interest in that forces impacting the human lumbar vertebrae during fast walking are approximately 1x body weight, and during jogging they reach 1.75X body weight; during weight-lifting exercise done in the standing position (defined as a "nonweight bearing activity"), the lumbar spine has been reported to bear a load as much as 5—6X body weight. [5,10]

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Resistive Exercise Option

Site-Specific Resistive Exercise

Site-specific resistive exercise occurs when a specific muscle contracts against counter-resistance. The contracting muscles and their attachments to the tendinous, ligamentous, and bony structures are therefore site-specific.

Isometric Resistive Exercise

An isometric resistive exercise occurs when a muscular contraction force is applied against an immovable resistance so that no muscle-shortening occurs. An example of an isometric resistive exercise is an attempt to lift a fixed, horizontal bar. The biceps, forearm, and hand muscles forcibly contract against the bar, but the resistance cannot be moved.

Isotonic Resistive Exercise

An isotonic resistive exercise occurs when muscle contraction and shortening occur under a constant load. An example of an isotonic resistive exercise is the lifting of a weighted object or load *(e.g.,* barbell) when the contraction of the muscle is sufficiently strong to do so.

Isokinetic Resistive Exercise

An isokinetic resistive exercise involves the use of a mechanical device to regulate the rate of the lifting motion. The resistance is adjusted throughout the exercise to match the strength of the muscles because the torque angle varies through a range of motion. Cybex equipment (Cybex, Ronkoncoma, New York, NY) are examples of isokinetic resistive exercise devices.

Advantages of Isometric Exercises

Isometric resistive exercises have been shown to be as efficient as isotonic and isokinetic exercises for muscle strengthening and have demonstrated effectiveness in strengthening weakened muscles adjacent to arthritic joints.[26] More to the point, in addition to their muscle-strengthening effects for patients with osteoporosis, isometric exercises and other forms of resistive exercise have a site-specific effect on bone mineralization.[6,9,10,14,17,24] Isometric exercises have an advantage to other resistive exercises because skeletal structures that are re-

sisted are not required to move during isometric exercise and therefore can be positioned to minimize pain and maximize the force that can be applied when the muscles contract.[26] Other types of resistive exercise require movement and therefore can produce pain, such as when a patient with a painful shoulder attempts to raise a weight overhead.

• Activity-Related, Site-Specific, Bone Mineral Enhancement in Humans

A review of the published literature in a Medlars search for all reports relating to exercise, osteoporosis, bone densiometry, and weight-bearing and resistive exercises published between June 1984 and December 1994 revealed that there were positive, site-specific correlations among exercises, bone mineralization, and bone structure. This was shown by studies comparing bone and muscle hypertrophy of the dominant hands and forearms of tennis players; the forearms and spines of male swimmers; the feet of ballet dancers; the femurs of runners; and the forearm bones of weight lifters, rowers, and laborers with that of office workers.[1,10] Further, the earlier the commencement of vigorous exercise, specifically if it occurred in preadolescence and adolescence rather than in adulthood, the larger the bone growth and the greater the amount of bone mineralization.[27] Thus, the time to begin an exercise regimen that will result in optimal development of bone structure is during the early years of growth and development of the human body.[27]

Physically active lifestyles and avoidance of bone mineral-depleting substances such ~ cortisone, ocher drugs, and tobacco are associated with good bone mineralization.[10,24] Excessive exercise, however, can result in low testosterone levels in men or low estrogen levels, amenorrhea, and subsequent bone demineralization in women.[1,24] Interestingly, whereas there is a limit to the osseous tissue that can be added to normal, healthy bone through exercise, individuals with osteoporosis and the lowest bone mass tend to show a greater bone mineralization response from exercise.[11,24]

• There are Many Bones of Contention

Confusion about the role of exercise on bone mineral density stems from the confounding of a number of variables in many of the reported studies. Clearly, there are differences in the impact of exercise on growing bone; the bones of patients with anorexia, rheumatoid arthritis, or spinal cord injury; adult bone; early menopausal bone; late menopausal bone; and the bone of aged adults (men and women) with or without osteoarthritis.[9,10,11]

The variables in patient selection also can include diverse ethnicity; obfuscating factors such as smoking, drinking, medications, and calcium supplementation; and compliance with dietary and/or exercise regimens.[9,24,27] Even in the studies in which these variables have been carefully addressed, however, there is often a failure to differentiate the specific type of exercise and/or to equate walking with other exercises such as resistive, endurance, or aerobic exercises.[7]

Bone Mineral Density Measurement Bias

Further confusion can be attributed to the method of bone mineral density measurement and the duration of the exercise regimen.[9] Studies using single or dual photon absorptiometry or computed axial tomography can lack the precision and/or diagnostic accuracy of dual energy x-ray absorptiometry to detect a significant change in bone mineral density in a study period of 1 year or less.[11,24]

Bone Mineral Density Preservation and/or Enhancement

Another factor that has obscured the benefits of exercise on bone mineralization is the lack of emphasis on the value of preserving bone mineral density in patients who otherwise would be placed at greater risk for fracture as a consequence of the normal bone attrition ($^1/_2$-1 % bone mineral loss per year) in the late postmenopausal period or in aging males.[6,11,14,17,24] This point takes on added significance when it is realized that over a period of 10 years, the inhibition of bone mineral loss by any means would result in a net 5—10% "gain" in bone mineral density. Therefore, the fact that discontinuing bone mineral-enhancing exercise therapy, or other therapy, results in a resumption of demineralization underscores the positive effect of exercise on bone mineralization.[4]

Although the inverse correlation of fracture risk with bone mineral density is well established, it is also clear that bone mineralization is not the only factor in bone structure that is associated with a fracture risk.[1,10,11,21,24] For example, increased fracture risk also is associated with bone enhanced with high doses of fluoride.[21]

• Is Resistive Exercise the Answer?

Whereas there is controversy about whether walking is beneficial for enhancing bone mineralization, there is extensive documentation that exclusively attributes the enhancement of bone mineral density to resistive exercise.[1,6,10,11,14,22]

Tables 1 and 2 list 11 of the prospective studies published between July 1990 and December 1994 found in the Medlars search and one additional study in 1995 of the effects of exercise on osteoporosis in postmenopausal women. Criteria for inclusion in Tables 1 and 2 included case randomization of at least 20 individuals to exercise or control groups and control for confounding factors of medication, calcium intake, and physical activity.[2,7,12,14—16,13—20,23,27]

Of the 12 studies, six primarily addressed the impact of resistive exercise with no change in weight-bearing activities on osteoporosis (see Table 1); the remaining six studies primarily addressed the impact of weight-bearing and/or aerobic exercise on osteoporosis (see Table 2).[2,7,12,14_16,18—20,23,27]

Table 1. Prospective Studies of the Impact of Resistive Exercise on Bone Mineral Density, in Postmenopausal Women (1990-1995)*

Year	Reference Number	Total Number of Volunteerst	BMD Evaluation Months	Method	Results (P < 0.05)
1991	16	20	12	DPA	Spine + ‡
				SPA	Forearm +
1991	7	78	12	OXA	Spine +
					Hip §
1992	23	49	12	DPA	Spine 0i
					Hip 0
1992	19	120	12	SPA	Forearm 0 ¶
1993	20	47	12	CT	Spine +
1994	14	39	12	CT	Spine +
				DPA	Spine §
					Hip 0
				SPA	Forearm 0

* No studies met the prospective study criteria in 1990 or 1995.
t 51 men also were studied and did show an increase in forearm BMD.
‡ Exercise combined with estrogen and calcium treatment increased BMD.
§ Attenuated BMD loss.
ll Volunteers in the control groups were vigorous exercisers.
¶ Aerobic and weight-bearing exercise.
BMD = bone mineral density. DPA = dual-photon absorptiometry. SPA = single-photon absorptiometry. CT = computed homography. + = increased bone mineral density. 0 = no effect

The Case for Resistive Exercises

It is clear from studies reported to date is that walking for exercise may have positive psychological and circulatory benefits, but that unlike running it does not stimulate bone mineralization consistently in the spine or hip. In one study the effects of weight-bearing exercise was associated with enhanced bone density only in the foot. [1,4,10,14,17]

Year	Reference Number	Total Number of Volunteerst	Months	BMD Evaluation Method	Results (P < 0.05)
1991	2	50	14	SPA	Forearm 0 ‡
1991	7	78	12	DXA	Spine 0
					Hip 0
1991	15	36	12	CT	Spine +
				DPA	Spine 0
					Hip 0
				SPA	Forearm 0
1993	18	168	24	DXA	Spine 0
					Hip 0
1993	12	55	12	SPA	Forearm 0
				DPA	Spine §
1995	17	168	24	DXA	Spine 0
					Hip §
					Mid tibia 0
					Ankle 0

* No studies met the prospective study criteria in 1990 or 1994.
t 51 men also were studied and did show an increase in forearm BMD.
‡ Aerobic and weight-bearing exercise.
§ Attenuated BMD loss
SPA = single-photon absorptiometry. DXA = dual x-ray absorptiometry. CT = computed tomocraphy. DPA = dual-photon absorprometry. + = increased bone mineral density. 0 = no effect.

In addition to the improved bone mineralization resulting from strengthening exercises, the concomitant enhancement of muscle strength may provide a basis for better coordination, balance, and resiliency for protection against falls and fractures.[10,11,14] If site-specific resistive exercises provide the greatest potential benefit from the standpoint of bone mineralization, muscular control, and fracture prevention for the upper and lower extremities and the spine, then a number of practical issues should be considered.

Exercise Risk Avoidance. The risks of exercise are clearly an issue. A patient who is to participate in an exercise program should be evaluated medically, particularly for cardiovascular and musculoskeletal health. The exercises should not risk cardiovascular complications and should be consistent with the patient's overall physical capabilities. [6,11] The status of arthritic joints, neuromuscular diseases, congenital and post-traumatic deformities, and myofascial and periarticular disorders must be evaluated so that exercises can be modified appropriately to avoid trauma for the patient.[6] Further, because the strengthening effects of isometric, isokinetic, and isotonic resistive exercises have been shown to be roughly equivalent, the advantages of relatively pain-free joint positioning for patients with arthritic disorders makes isometric exercise the preferable option.[26]

Two issues that often are not considered by health professionals, but that need further emphasis are the possibilities that lumbar flexion-abdominal crunching exercises done by patients with severe osteoporosis can predispose them to spinal compression fracture and that overly stressful exercise with no proper conditioning, even in healthy adults, can lead to stress fractures.[1,620,24]

Cost Factors. Weight-bearing exercises such as walking may provide less than optimal benefits in bone mineralization, but they are potentially the most affordable (although the costs can escalate when stairclimbing and treadmill apparatuses are used). Resistive exercises using light weights, isometric or minimally isotonic resistances such as compressible balls or cushions, or elastic bands are readily affordable (Appendix A).[1] A combination of inflatable ball and elastic band isometric exercises done by 20 postmenopausal patients in a preliminary, unpublished study by the authors demonstrated that 10 minutes of exercise done 6 days per week for 8 weeks produced significant ($P < .05$) strength increases in the hands (grip), biceps, quadriceps, and neck extensor muscles (Appendix B).

Compliance/Adherence. For an exercise program to succeed, it must be adhered to by the patient. If the cost is prohibitive or if the exercises produce pain or fatigue, then it is unlikely that the patient will continue to exercise. Once these factors are dealt with, other factors must be considered.

The time required to perform the exercise is a major

consideration. If the exercise requires specialized equipment and can be done only at an institution or facility away from home, which involves scheduling issues and travel time, successful continuation of what is in essence a lifetime commitment to the exercise program will be compromised. Exercises that require more than 10 minutes and chat must be done once or twice daily, 7 days per week create a potential obstacle to compliance and may result in all but the most committed patients leaving the exercise program.[9,17,24]

Conclusion

Weight-bearing exercises such as walking and jogging, which play a very important role in aerobic conditioning, can have a modest benefit in the prevention and treatment of osteoporosis, whereas sire-specific resistive exercises appear to have a more consistent effect on bone mineralization and muscle strength. Weight-bearing and resistive exercise can be performed inexpensively. The time commitment and possible environmental constraints are more prohibitive for walking and jogging than for a home, resistive exercise regimen, which increases the potential for adherence to a resistive exercise regimen rather than a regimen of weight-bearing exercises for preserving and/or enhancing skeletal mineralization.
to document the efficacy of site-specific resistive exercises and more vigorous weight-bearing exercises such as jogging in maintaining sufficient bone mineral density. Further prospective studies of exercises to enhance muscle strength and bone mineralization that are of sufficient duration to determine the effect of these exercises on fracture prevention are clearly needed. These studies will require rigid criteria for evaluation and should include resistive exercises that are brief, simple, inexpensive, and safe to perform.

References

1. Allen S. Exercise considerations for postmenopausal women with osteoporosis. Arthritis Care Res 1994;7:205—14.
2. Blumenthal JA, Emery CF, Madden DJ, et al. Effects of exercise training on bone density in older men and women. J Am Geriatr Soc 1991;39:1065—71.
3. Dalsky C, Stocke KS, Ehsani AA. Weight bearing exercise training and lumbar bone mineral Content in postmenopausal women. Ann Inc Med 1988;108:824—228.
4. Fonwood MR, Burr DB. Physical activity and bone massage: Exercises in futility? Bone Miner 1993;21:89—112.
5. Granhed H, Jonson R, and Hansson 1. The loads on the lumbar spine during extreme weight lifting. Spine 1987;12: 146—9.
6. Gutin B, Kasper MJ. Can vigorous exercise play a role in osteoporosis prevention? A review. Osteoporos Int 1992;2:55—69.
7. Heikkinen J, Kurttila-Matero E, Kyllonen E, Vuori J, Takala T, Vaananen HK. Moderate exercise does not enhance the positive effect of estrogen on bone mineral density in post-menopausal women. Calcif Tissue Inc 1991; 49(Supp):83—4.
8. Heislein DM, Harris BA, jetre AM. A strength training program for postmenopausal women: A pilot study. Arch Phys Med Rehabil 1994;75:198—204.
9. Lohman T, Going S, Pamenter R, et al. Effects of resistance training on regional and total bone density in premenopausal women: A randomized prospective study. J Bone Miner Res 1995;101015—24.
10. Marcus R, Drinkwater B, Dalsky G, et al. Osteoporosis and exercise in women. Med Sci Sports Exerc 1992;24:5301—7.
11. Martin A. Osteoporosis: A geriatric public health issue. Top GenatrRehabil 1995;10:1-11.
12. Martin D, Notelovitz M. Effects of aerobic training on bone mineral density of postmenopausal women. J Bone Miner Res 1993;18:931—6.
13. Menkes A, Mazel S, Redmond RA, et al. Strength training increases regional bone mineral density and bone remodling in middle-aged and older men. J Appl Physiol 1993;74:2478—84.
14. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteopororic fractures: A randomized controlled trial. JAMA 1994;272:1909—14.
15. Nelson ME, Fisher EC, Dilmanian FA, Dallal GE, Evans WJ. A 1-y walking program and increased dietary calcium in postmenopausal women: Effects on bone. Am J Clin Nutr 1991;53:1304—11.
16. Notelovitz M, Martin D, Tesar R, et al. Estrogen therapy and variable resistance weight training increase bone mineral in surgically menopausal women. J Bone Miner Res 1991;6:583—90.
17. Prince R, Devine A, Dick I, et al. The effects of calcium supplementation (milk powder or tablets) and exercise on bone density in postmenopausal women. J Bone Miner Res 1995;10:1068—75.
18. Prince R, Devine A, Dick 1, Kerr D, Criddle A, Price R. A randomized trial of the effects of calcium supplementation, as a tablet or milk powder, and exercise on bone density on women ten years past the menopause. J Bone Miner Res 1993;8(Suppl):130.
19. Prince RL, Smith M. Dick LM, et al. Prevention of postmenopausal osteoporosis: A comparative study of exercise, calcium supplementation and hormone replacement therapy. N EngI J Med 1991;225:1191—5.
20. Revel M, Mayoux-Benhamou MA, Rabourdin JP, Bagheri F, Roux C. One-year psoas training can prevent lumbar bone loss in postmenopausal women: A randomized controlled trial. Calcif Tissue Int 1993;53:307-11.
21. Riggs BL, Hodgson SF, O'Fallon WM, et al. Effect of fluoride treatment on the fracture rate in postmenopausal women with osteoporosis. N EngI J Med 1990;322:802—9.
22. Sinaki M, Mikkelsen BA. Postmenopausal spinal osteoporosis. Arch Phys Med Rehabil 1984;65:593—6.
23. Smidt GL, Shen-Yu Lin MA, O'Dwyer KD, Blanpied PR. The effect of high intensity trunk exercise on bone mineral density of postmenopausal women. Spine 1992;17:280—5.
24. Snow-Harter C, Marcus R. Exercise, bone mineral density, and osteoporosis. Exerc Sport Sci Rev 1991;19:35l.-88.
25. Swezey RL. Essential Therapies for Joint, Soft Tissue and

Disk Disorders. Philadelphia: Hanley & Belfus, Inc., 1988:28, 29, 33, 81, 84.
26. Tucker L, Mortell R. Comparison of the effects of walking and weight training programs on body image in middle-aged women: An experimental study. Am J Health Promotion 1993; 8:34-42.
27. Welten, DC, Kemper HCG, Post GB, et al. Weight bearing activity during youth is a more important factor for peak bone mass than calcium intake. J Bone Miner Res 1994;9:1059-96.

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Appendix A. Site-Specific Exercise Options

Method	Site	Duration (min)	Frequency (days/wk)	Location (home and/or gym)	Cost	Reference Number
Isotonic						
Free weights	UE/LE	60	3	Home/gym	$	10
Overhead pulley weights	UE/LE	45	2	Home/gym	$$	6
Isometric						
Elastic strap	UE	45	3	Home	$	8
Inflated ball	UE/LE/N/B*	10-20	3-6	Home	$	25
Pneumatic resistance	UE/LE/N/B	60	3	Gym	$$	1
Isokinetic						
Variable resistance	UE/LE/N/B	15-20	3	Gym	$$$	1

UE = upper extremity. LE = lower extremity. N = neck. B = back. $ = low. $$ = moderate. $$$ = high.
* Illustrated below.

Appendix B. Recommended Site-Specific Exercises for Osteoporosis

1. Lifting free weights or pulley-attached weights
2. Combination of minimally expandable elastic strap-stretching and inflatable ball squeezing.

These exercises should be applied to the key areas, e.g., neck, back, and upper and lower extremities, two to three times per week for 10-45 minutes (depending on length warm-up and rest periods). When properly performed, these exercises are safe, convenient, and economical, and have been demonstrated to have a strengthening effect.

Meetings of Interest for Spine Physicians and Surgeons

International ISSLS Fellowship

The International Society for the Study of the Lumbar Spine was founded in 1974 to bring together those individuals throughout the world, who, by their contributions and activities in the area of research and clinical study were interested in the lumbar spine in health and in disease. Its further purpose was to serve as a forum for the exchange at information of an investigative and clinical nature which relates to low back pain and disability.

This has been accomplished by holding annual meetings throughout the world. Unfortunately, there are many countries, especially in underdeveloped areas, that are not represented. The members of the Society feel that a great deal of information could be exchanged if these countries actively participated.

The purpose of the International Fellowship Fund is to identify appropriate individuals in underrepresented/ underdeveloped areas and financially sponsor them to attend and actively participate in the Society's meetings.

If anyone would like to attend next year's meeting in Singapore, June 2—6, 1997, the applicant should send a letter of application briefly outlining their work along with a curricutum vitae, a list of their publications, in English, and two letters of sponsorship from their superiors. They should also send an abstract of a paper or poster that they would present at the meeting. The applicant should have a demonstrated interest in clinical spine or nonclinical spine-related research. Five copies of this material should be in the Society's office in Toronto by January 1,1997. The committee will meet shortly after to decide which of the applicants will receive this award for the 1997 meeting.

Send applications to: The International Society for the Study of the Lumbar Spine, Sunnybrook Health Science Centre, A 309, 2075 Bayview Avenue, Toronto, Canada M4N 3M5. Tel: 416-480-4833; Fax: 416-480-6055.

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March 16—20, 1997
Kamuela, Hawaii