Spine Update

Exercise for Osteoporosis—Is Walking Enough?: 2809
The Case for Site Specificity and Resistive Exercise

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.

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

Robert L. Swezey, MD, FACP, FACR

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.5 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

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, Ronkonkoma, 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. 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 densitometry, 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. 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. 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. Physically active lifestyles and avoidance of bone mineral-depleting substances such as cortisone, ocher drugs, and tobacco are associated with good bone mineralization. Excessive exercise, however, can result in low testosterone levels in men or low estrogen levels, amenorrhea, and subsequent bone demineralization in women. 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.

- 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. 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. 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.

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. 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.

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. 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.

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. For example, increased fracture risk also is associated with bone enhanced with high doses of fluoride.

- 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. 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.

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).
Exercise for Osteoporosis—Is Walking Enough? • Swezey 2811

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Reference Number</th>
<th>Total Number of Volunteers</th>
<th>Months</th>
<th>BMD Evaluation Method</th>
<th>Results (P &lt; 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>16</td>
<td>20</td>
<td>12</td>
<td>DPA</td>
<td>Hip 0</td>
</tr>
<tr>
<td>1991</td>
<td>7</td>
<td>78</td>
<td>12</td>
<td>SPA</td>
<td>Forearm + Spine +</td>
</tr>
<tr>
<td>1992</td>
<td>23</td>
<td>49</td>
<td>12</td>
<td>OXA</td>
<td>Hip 0</td>
</tr>
<tr>
<td>1992</td>
<td>19</td>
<td>120</td>
<td>12</td>
<td>SPA</td>
<td>Forearm 0</td>
</tr>
<tr>
<td>1993</td>
<td>20</td>
<td>47</td>
<td>12</td>
<td>CT</td>
<td>Spine + Hip 0</td>
</tr>
<tr>
<td>1994</td>
<td>14</td>
<td>39</td>
<td>12</td>
<td>DPA</td>
<td>Spine + Hip 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SPA</td>
<td>Forearm 0</td>
</tr>
</tbody>
</table>

* No studies met the prospective study criteria in 1990 or 1995.
† 51 men also were studied and did show an increase in forearm BMD.
§ Attenuated BMD loss.
¶ Aerobic and weight-bearing exercise.
BMD = bone mineral density. DPA = dual-photon absorptiometry. SPA = single-photon absorptiometry. CT = computed tomography. DXA = dual x-ray absorptiometry. + = increased bone mineral density. 0 = no effect.

The Case for Resistive Exercises

It is clear from studies reported to date 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

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 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. 1,6,26,24

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 issue. 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.\(^3,17,24\)

### 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 site-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

25. Swezey RL. Essential Therapies for Joint, Soft Tissue and
Swezey 2813

Appendix A. Site-Specific Exercise Options

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

* 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 curriculum 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.

Neuroradiology: The Essentials
January 23-26, 1997
The Rittenhouse Hotel, Philadelphia, Pennsylvania
Contact: Janice Ford
Hospital of the University of Pennsylvania
3400 Spruce Street, 1 Silverstein Building
Philadelphia, PA 19104
Tel: 215-662-7825
Fax: 215-349-5925

Thoracic Approaches for the Treatment of Thoracic Spinal Pathology
February 6-8, 1997
Barrow Neurological Institute of St. Joseph’s Hospital and Medical Center, Phoenix, Arizona
Contact: Norma Fry
Barrow Neurological Institute
350 West Thomas Road
Phoenix, AZ 85013
Tel: 602-406-3067
Fax: 602-406-4104

20th Annual Winter Skeletal Symposium: Musculoskeletal MRI
March 10—14, 1997
Crested Butte, Colorado
Contact: Janice Ford
Hospital of the University of Pennsylvania
3400 Spruce Street, 1 Silverstein Building
Philadelphia, PA 19104
Tel: 215-662-7825
Fax: 215-349-5925

Ninth Annual Ski With the Spine Center
January 12-17, 1997
Whistler, British Columbia, Canada
Sponsored by: Tampa General Healthcare, Tampa, Florida
Contact: Connie Kenyon
4175 E. Fowler Avenue
Tampa, FL 33617
Tel/Fax: 813-632-0395

Back Problems in the Productive Years
March 14—15, 1997
Houston Marriot Medical Center Hotel, Houston, Texas
Contact: Lila Lerner, Conference Coordinator
Office of Continuing Education
Baylor College of Medicine
One Baylor Plaza, S104
Houston, TX 77030
Tel: 713-798-6020
Fax: 713-798-7955

15th Course for Percutaneous Endoscopic Spinal Surgery and Complementary Techniques
January 23—24, 1997
Hospital Neumunster, Zollikerberg/Zurich, Switzerland
Contact: PD Dr.med. Hj Leu
Prisma Spine Unit
Spital Neumunster
CH-8125 Zollikerberg/Zurich
Switzerland
Fax: 41-1-391-24-38

NASS/JSRS Second Combined Spine Conference: Spine Across the Sea ’97
March 16—20, 1997
Kamuela, Hawaii