Musculoskeletal Challenges of Osteoporosis: Therapeutic Exercise/Strength Training A Review

Osteoporozun Kas ve İskelet Sistemi Sorunları: Tedavi Edici ve Kuvvetlendirme Egzersizleri. Bir Derleme

Mehrsheed Sinaki

Professor of Physical Medicine and Rehabilitation, Mayo Clinic College of Medicine, Department of Physical Medicine and Rehabilitation, Mayo Clinic, Rochester, MN, USA

Summary

Combining pharmacotherapy with non-pharmacotherapy is fundamental to the successful management of osteopenia and osteoporosis. The choice of pharmacotherapy depends on the patient's age, bone mineral density and serum biochemical markers of bone. HRT should not be used for treatment of osteoporosis. As with pharmacotherapy, rehabilitation management is challenging and innovative. Non-pathologic spontaneous vertebral fractures that occur at the level of the spine are purely osteoporosis-related. On the other hand, the majority of non-vertebral fractures that are of special clinical significance are fall-related. Therefore, reducing the risk for fracture through the prevention of falls is as important as increasing bone mass. *(From the World of Osteoporosis 2009;15:52-8)*

Key words: Osteoporosis, non-pharmacologic therapy, exercises

Özet

Farmakoterapi ile nonfarmakolojik tedavilerin kombine edilmesi osteopeni ve osteoporoz tedavisinin başarısı için esastır. Farmakoterapinin seçimi hastanın yaşı, kemik mineral yoğunluğu ve biokimyasal kemik belirleyicilerine göre yapılır. HRT osteoporoz tedavisi için kullanılmamalıdır. Farmakoterapi gibi, rehabilitasyon uygulamaları da zorluklarla karşılaşabilir ve yeni yaklaşımlar gerekebilir. Omurga düzeyinde oluşan travmatik olmayan spontan vertebra kırıkları osteoporoza bağlıdır. Diğer yandan özel klinik önemi olan vertebra dışı kırıkların çoğunluğu düşme ile ilişkilidir. Bu nedenle düşmeleri önleyerek kırıktan korunmak kemik kütlesini artırmak kadar önemlidir. *(Osteoporoz Dünyasından 2009;15:52-8)*

Anahtar kelimeler: Osteoporoz, nonfarmakolojik, tedavi, egzersiz

"Bone, to be maintained, needs to be mechanically strained-within its biomechanical competence".
Mehrsheed Sinaki, M.D.

Combining pharmacotherapy with non-pharmacotherapy is fundamental to the successful management of osteopenia and osteoporosis (1,2). The musculoskeletal and psychological benefits provided by rehabilitation measures are of great importance for improvement of the patient's quality of life. Musculoskeletal rehabilitation and nonpharmacologic interventions consist of exercise, physical management of pain, proper use of orthotics, and prevention of falls and fractures (1,2). Bone mass is frequently considered to be the most important determinant of fragility, but it explains only less than half of the observed fracture risk at the level of the spine. Non-pathologic spontaneous vertebral fractures that occur at the level of the spine are purely osteoporosis-related. On the other hand, the majority of non-vertebral fractures that are of special clinical significance are fall-related. Therefore, reducing the

Address for Correspondence/Yazışma Adresi: Mehrsheed Sinaki, M.D., M.S., Professor of Physical Medicine and Rehabilitation, Mayo Clinic College of Medicine, Department of Physical Medicine and Rehabilitation, Mayo Clinic, Rochester, MN, USA Phone: 507-284-4904 Fax: 507-284-3431 E-mail: sinaki.mehrsheed@mayo.edu
Received/Geliş Tarihi: 31.03.2009 **Accepted/Kabul Tarihi:** 18.04.2009

Note: Presented at the 3rd National Osteoporosis Congress. Antalya, Turkey, October 15-19, 2008

risk for fracture through the prevention of falls is as important as increasing bone mass. However, the prevention of falls is more challenging than improving bone mass. Falls are multifactorial, and prevention or reduction of falls requires a combination of pharmacologic and nonpharmacologic interventions. Risk of falls can be extrinsic, i.e. related to environmental factors, or intrinsic, i.e. related to musculoskeletal and neuromuscular health of the individual. Table 1 shows factors that increase risk of falls (3).

In men and women, the combination of age-related sarcopenia and reduction of physical activity can affect musculoskeletal health and contribute to the development of bone fragility and falls (4). Musculoskeletal-wise, women are more challenged than men since they start adulthood with lower muscle strength (5) and lower bone mass than men. Reduction in the biomechanical competence of the axial skeleton can result in challenging complications (6). Complications of osteoporosis can vary from "silent" compression fractures of vertebral bodies to sacral insufficiency fractures to "breath-taking" fractures of the spine or femoral neck. The exponential loss of axial bone mass at the postmenopausal stage is not accompanied by an incremental loss of muscle strength. Loss of muscle strength follows a more gradual course and is not affected significantly by a sudden hormonal decline, as is the case with bone loss. With increasing age, axial loss of muscle strength is more significant in women than appendicular muscle loss (7). This muscle loss may contribute to osteoporosis-related axial disfigurations as well as increased incidence of falls.

Skeletal structures are physically and kinematically acted upon by muscles. Axial and appendicular muscle strength in boys and girls is about the same until age 10 when a disparity begins to develop (5). Muscle strength decreases with age in men and women (Fig 1) (4).

Kyphosis commonly occurs with reduced back muscle strength, vertebral bone loss or fracture. Hyperkyphosis results in back pain, decreased vital capacity, and increased risk of further vertebral fractures and unsteadiness of gait (8). In many individuals, it also creates a negative self-image (9). In severe kyphotic posture, pressure of the lower part of the rib cage over the pelvic rim causes significant flank pain, tenderness and compromises breathing (2). In healthy posture, there is sufficient space between the lower ribs and the iliac crest so that no contact

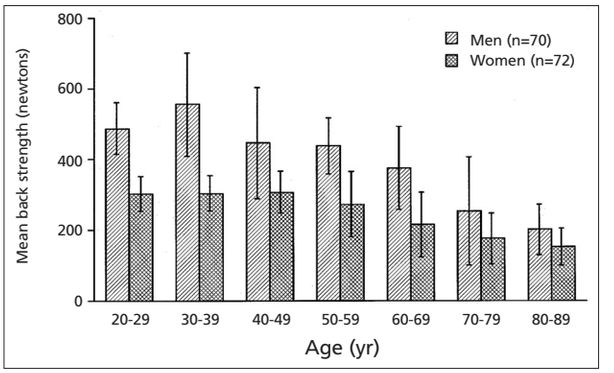

Figure 1. Back extensor strength in men and women during the third through ninth decades
(From Sinaki M, Nwaogwugwu NC, et al. Am J Phys Med. 80(5): 330-38, 2001)

Table 1. Contributing factors in risk for falls

Extrinsic
Environmental
Obstacles, slippery floors, uneven surfaces, poor illumination, stairs not well defined, pets, icy sidewalks
Extraskeletal – inappropriate footwear, obstructive clothing
Intrinsic
Intraskeletal – lower extremity weakness (neurogenic or myopathic)
Balance disorder (vestibular, peripheral neuropathy, hyperkyphosis)
Visual impairment, bifocals
Vestibular changes
Cognitive decline
Decreased coordination (cerebellar degeneration)
Postural changes, imbalance, gait unsteadiness
Gait apraxia
Reduced muscle strength
Reduced flexibility
Respiratory (orthopnea)
Postural hypotension
Cardiovascular deconditioning
Iatrogenically reduced alertness

Modified from Sinaki M: Prevention of Hip Fracture: Physical Activity. IN: Senile Osteoporosis. J. D. Ringe and J. P. Meunier (eds); pp 99-115, 1996 and Sinaki M. Falls, Fractures and Hip Pads. Current Osteoporosis Reports: Evaluation and Management. 2(4):131-137. December, 2004

occurs, even on lateral bending of the trunk. In cases of severe osteoporosis with compression fractures, dorsal kyphosis, loss of height, and iliocostal contact occurs (2). The latter can result in iliocostal friction syndrome and flank pain. Fortunately, kyphotic posture and vertebral fractures are no longer disorders about which nothing can be done. Scapular retraction and dynamic back strengthening can decrease thoracic hyperkyphosis at any age (10). Helping the patient to decrease kyphotic posturing through recruitment of back extensors for provision of better dynamic/static posturing can reduce pain, increase mobility, reduce depression and improve the patient's quality of life. The author's Spinal Proprioceptive Extension Exercise Dynamic (SPEED) program can help to decrease thoracic hyperkyphosis and risk of falls (11). Bracing, unless geared to a posture training type of program, can decrease back extensor strength. (Fig 2 a, b, c, d, e, f, g) (12). In fact, the use of rigid back supports can result in selective weakness in back extensors, the major supportive muscles of the back (Fig 3). To be helpful, spinal orthotics need to decrease pain and expedite ambulation and mobility. Orthotics that function through increment in intra-abdominal pressure, however, are contraindicated in cases of a) hiatal hernia; b) iliocostal friction syndrome; c) severe kyphosis; d) COPD; and e) significant loss of height (2).

Osteoporosis remains asymptomatic until fracture occurs. Back pain is usually the osteoporotic patient's main complaint. Vertebral compression fractures often occur in the mid-thoracic and upper lumbar vertebral bodies (Fig 4), followed in order of frequency by low thoracic and lower lumbar vertebral bodies. The cervical and upper thoracic vertebrae are rarely, if ever, involved (13). Back pain is a major cause of depression and disability in osteoporotic patients (14). Osteoporosis-related back pain is of two types - acute and chronic (Tables 2 and 3). Management of acute back pain differs from that of chronic back pain. Proper management of pain related to acute vertebral compression fractures can reduce the risk of developing chronic pain syndrome. Limited bed rest (1-2 days), non-codeine derivative analgesics, sedative physical therapy and proper bracing are some of the helpful measures. Calcitonin has both antiresorptive and analgesic effect and may be used for a few months (15). Back pain and immobility can decrease with the use of spinal orthoses. However, continuous use of spinal orthotics can result in truncal muscular weakness and further complicate the musculoskeletal challenges related to osteoporosis (Fig 3) (16). Sacral insufficiency fractures require sedative physical therapy and reduction of weightbearing with use of gait aids and orthoses (17). One of the major musculoskeletal challenges of osteoporosis is spinal disfiguration such as kyphoscoliosis which results in chronic back pain and also can contribute to falls and further fracture (16,17).

Proper exercise and rehabilitative measures have the potential to build bone mass and decrease the rate of bone loss. Not all types of physical exercises are osteogenic. Stronger back extensors have been proven to correlate with reduced kyphosis and a lower number of vertebral

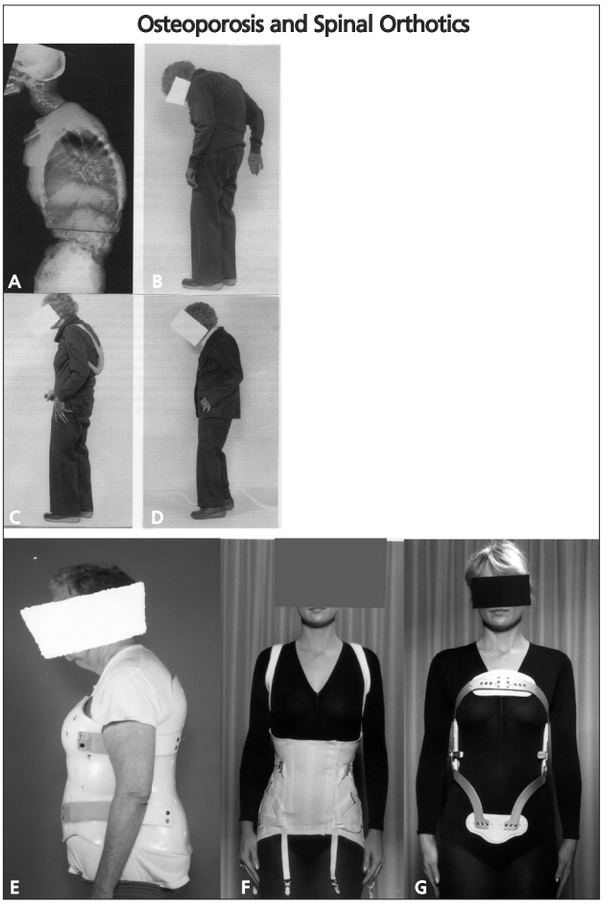

Figure 2. A, B: Radiograph and photo of an 86-year-old woman with severe osteoporosis that made her ambulation difficult
C: The same woman wearing a weighted kypho-orthosis.
D: Long-term follow-up (6 years later at age 92) patient's posture significantly improved. (From Sinaki M. Rehabilitation of Osteoporosis, Physical Medicine and Rehabilitation, State of the Art Reviews, 1995)
E: Rigid back support-bivalved body jacket. Brace is made of polypropylene and is custom-fitted. (From Sinaki M. Prevention of hip fracture: physical activity. In: Ringe JD, Meunier PJ, editors. Osteoporotic fractures in the elderly: clinical management and prevention. Stuttgart: Georg Thieme Verlag: 1996. p. 99-115)
F: Thoracolumbar support with rigid or semirigid stays. Addition of shoulder straps further decreases kyphotic posture or reminds the patient to avoid severe stooping. Padding can be added to the shoulder straps to decrease pressure over bony prominences. (From Sinaki M. Exercise and physical therapy. In: Riggs BL, Melton LJ III, editors. Osteoporosis: Etiology, diagnosis, and management. New York: Raven Press; 1988. p. 457-79)
G: Jewett brace used to prevent lumbar and thoracic flexion when patient has acute pain caused by recent compression fracture of spine. Proper fitting requires proper contact at base of sternum and over pubic bone
(From Sinaki M. Exercise and physical therapy. In: Riggs BL, Melton LJ III, editors. Osteoporosis: Etiology, diagnosis, and management. New York: Raven Press; 1988. p. 457-79)

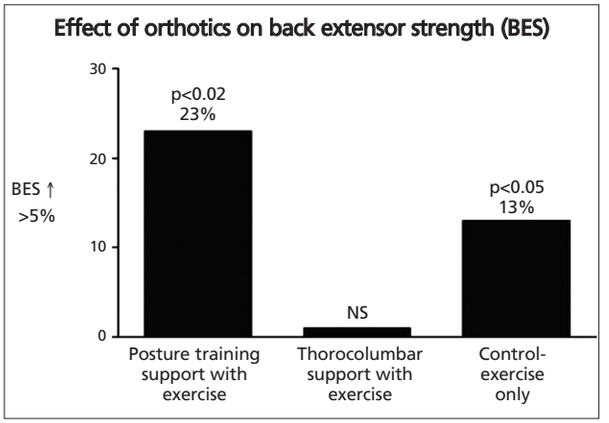

Figure 3. Control group performed exercise only; Posture Training Support (PTS) group used PTS and proprioceptive dynamic posture training; Thorocolumbar group used T-L brace and exercise

(data from Kaplan RS, Sinaki M, Hameister MD. Mayo Clin Proc 1996; 71:235-241)

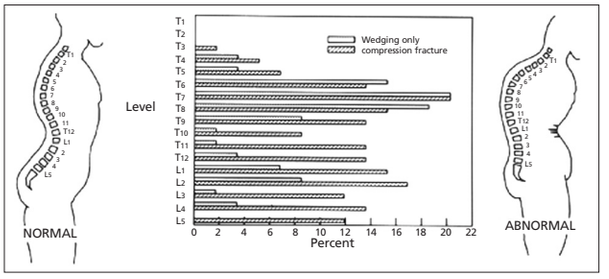

Figure 4. Osteoporosis-related incidence of wedging and compression fractures at various levels of the spine on radiographic evaluation

(From Sinaki M, Mikkelsen BA. Arch Phys Med Rehabil, 1984; 65(10):593-6)

fractures (Fig 5) (18). Research studies show that spinal extensor exercises are the preferred choice for strengthening back extensors (Fig 6) (13,19). The author has hypothesized that back exercises performed in a prone position, rather than in a vertical position, may have a greater effect on decreasing risk for vertebral fractures without resulting in compression fracture. One can theorize that the risk for vertebral fracture can be reduced through improvement in the horizontal trabecular connection of vertebral bodies (Fig 7) (20). Through understanding both the benefits and shortcomings of exercise, we can prescribe the proper program for prevention and treatment of osteoporosis and reduction of falls. To be oste-

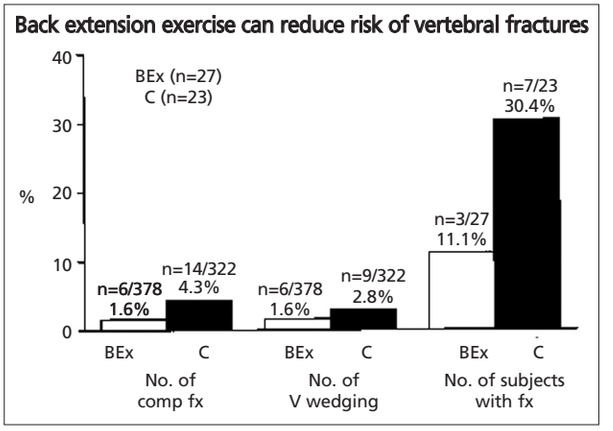

Figure 5. At 10-year follow-up, the number of vertebral compression fractures (Comp fx) was 14 in 322 vertebral bodies examined (4.3%) in the controls (C) and 6 fractures in 378 vertebral bodies examined (1.6%) in the back exercise (BEx) group (χ^2 test, p=0.029)

(From: Sinaki M. Op Int. Aug. 2003)

Table 2. Short-term management of acute pain in patients with osteoporosis

Bed rest (2 days). Significant bone loss is not likely to occur with 2 days of bed rest
Analgesics (avoid codeine derivatives)
Physical therapy: initially cold packs, then mild heat and stroking massage
Avoidance of constipation
Avoidance of exertional exercises
Lifting and standing principles to avoid strain on spine
Back support to decrease pain and expedite ambulation
Gait aids if needed

Modified from Sinaki M: Metabolic Bone Disease, Chap. 16, IN: Basic Clinical Rehabilitation Medicine, 2nd Ed.; edited by M. Sinaki, Mosby Year Book, Inc., Chicago, IL 1993. pp. 209-236

Table 3. Long-term management of chronic pain in patients with osteoporosis

Improve faulty posture, may need Posture Training Support (PTS)
Manage pain (ultrasound, massage, or transcutaneous electrical nerve stimulation)
If beyond correction, apply back support to decrease painful stretch of ligaments
Avoid physical activities that exert extreme vertical compression forces on vertebral bones
Prescribe a sound therapeutic exercise program
Start appropriate pharmacologic intervention

Modified from Sinaki M: Metabolic Bone Disease, Chap. 16, IN: Basic Clinical Rehabilitation Medicine, 2nd Ed.; edited by M. Sinaki, Mosby Year Book, Inc., Chicago, IL 1993

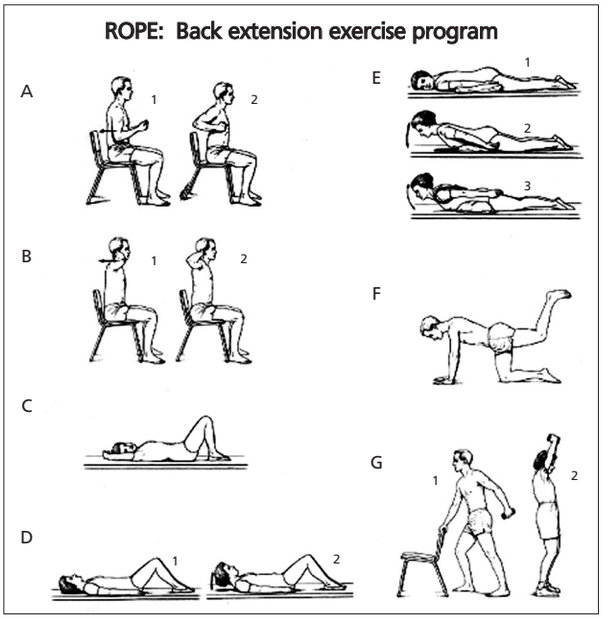

Figure 6. Nonstrenuous exercises for patients with severe osteoporosis. (A) Back extension exercise, in sitting position. This position avoids or minimizes pain in patients with severe osteoporosis. (B) Deep breathing exercise combined with pectoral stretching and back extension exercise. Patient sits on a chair, places hands at the level of head, and inhales deeply while gently extending the elbows backward. While exhaling, patient returns arms to the starting position. This is repeated 10 to 15 times. (C) Exercise to decrease lumbar lordosis with isometric contraction of lumbar flexors. (D) Technique of isometric exercise to strengthen abdominal muscles. (E) Extension exercises in prone position with pillow under abdomen (avoid hyperextension). (E3) To increase the effect of back extension strengthening, weight is added. (F) Exercise for improving strength in lumbar extensors and gluteus maximus muscles. (G) Specificity of exercises: muscle-strengthening and weight-loading exercises that may decrease bone loss. (These exercises were developed for the osteopenic spine by M. Sinaki through a grant from the Retirement Research Foundation. These techniques are designed to decrease strain on the spine despite weight lifting.) (G l) Shoulder extensors contribute to reduction of kyphotic posturing. Shoulder extensors can be strengthened with a proper combination of weightlifting and weight bearing exercises while balance is maintained. One knee is bent to avoid lumbar strain. To avoid straining the spine and to maintain balance, leaning or holding onto a steady object for support is recommended. Note: The amount of weight lifted is about l to 2 pounds, not to exceed 5 pounds. The amount of weight needs to be prescribed according to the patient's bone mineral density (status of osteoporosis) and the condition of the upper extremities. (G2) Bilateral or unilateral spine and hip weight-loading exercise. When weight is lifted above the head, knees should be bent slightly to avoid straining the lumbar spine. Note: The amount of weight lifted is about l to 2 pounds in each hand, not to exceed 5 pounds in each hand. The amount of weight needs to be prescribed according to the patient's bone mineral density (status of osteoporosis) and the condition of the upper extremities

(Al through B2, F, and G from Sinaki M. Metabolic bone disease. In: Sinaki M, editor. Basic Clinical Rehabilitation Medicine. 2nd edition. St. Louis: Mosby Year Book, 1993; p. 209-36. C,D, and E1,2 from Sinaki M. Exercise and physical therapy. In: Riggs BL, Melton U 111, editors. Osteoporosis: etiology, diagnosis, and management. New York: Raven Press; 1988. p. 457-79. E3 from PTS: Posture Training Support. Brochure Y32905. Jackson (Ml): CAMP Healthcare; 1998)

ogenic, the exercise stimulus must be loading type, not supportive (21,22). Devising an exercise program for the prevention and treatment of bone loss requires consideration of the subject's bone density, muscle strength, cognition, coordination, balance and cardiovascular health. Kyphoplasty and vertebroplasty can significantly decrease pain related to vertebral fracture. Our recent retrospective study showed that Rehabilitation of Osteoporosis Program–Exercise (ROPE) after vertebroplasty significantly decreased incidence of fracture recurrence (P=.001) (Fig. 8). In addition, pharmacotherapy combined with rehabilitation of osteoporosis program is more effective than pharmacotherapy alone (24).

Before prescribing an exercise program for osteoporotic individuals older than 65 years of age, several factors need to be considered: 1) the objective of the exercise program; 2) the biomechanical competence of the spine and musculoskeletal health in general; 3) the status of neuromuscular health; 4) cardiovascular fitness; 5) past history of sports activities and interest; and 6) the patient's environment (6).

Calcium and vitamin D are basic therapeutic options for osteoporosis prevention and management. Until recently, estrogen was commonly prescribed for postmenopausal syndrome and bone health. However, the Women's Health Initiative study concluded that the benefits of HRT do not outweigh the risks of long term treatment (25). At present, some of the benefits of HRT include reduction of hip fractures, colorectal cancer, and reduction of cognitive impairment. On the other hand, risks include an increased chance of breast cancer, coronary artery disease,

Figure 7. Model demonstrating back-strengthening exercise with a backpack containing sandbag weights

(From Sinaki M, et al. (1989) Mayo Clin Proc. 64:762-769

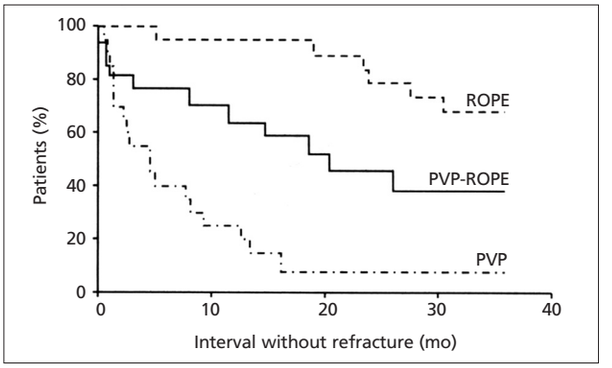

Figure 8. Survival plot showing the percentage of patients in each group with no refracture at various time points (P<.001). PVP=percutaneous vertebroplasty; ROPE=Rehabilitation of Osteoporosis Program-Exercise

(From Huntoon EA, et al. Mayo Clin Proc. January 2008:83(1):54-57

stroke, deep venous thrombosis, and cholecystitis. The effect of HRT on cardiovascular disease depends on the age of women. Recent reports indicate that women younger than age 60 who took hormones had a 39% reduction in total mortality as compared to women of a similar age who did not take the drug. Additional pharmacotherapy options include antiresorptive agents such as bisphosphonates in the form of alendronate or risedronate and bone-forming agents such as teriparatide. The choice of pharmacotherapy depends on the patient's age, bone mineral density and serum biochemical markers of bone. HRT should not be used for treatment of osteoporosis.

Bone loss and osteoporosis cause an imbalance in musculoskeletal stability. Increased bone porosity decreases the biomechanical competence of bone. Trauma to the skeletal structure can vary from gravity alone to the high impact of a moving, energized body part to the floor. The point of no return from fracture is defined by bone mass and resilience (16).

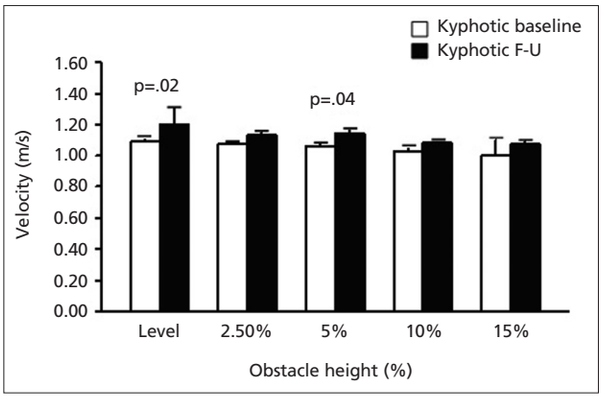

Figure 9. Anteroposterior velocity in subjects with osteoporosis-kyphosis at baseline and follow-up. After a 4-week trial of a spinal proprioceptive extension exercise dynamic (SPEED) program and spinal weighted kypho-orthosis, level walking and 5% obstacle walking improved. Error bars = 1 SD

(From Sinaki M, et al. (2005);80(7):849-855)

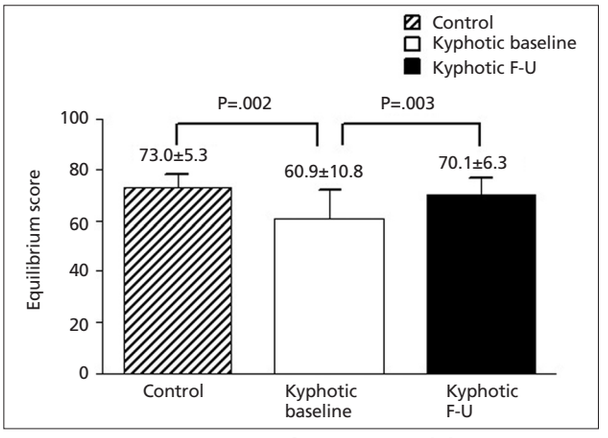

Figure 10. Composite score of computerized dynamic posturography in control subjects and subjects with osteoporosis-kyphosis at baseline and follow-up. Kyphotic subjects improved significantly after a 4-week trial of a spinal proprioceptive extension exercise dynamic (SPEED) program and spinal weighted kypho-orthosis. Data are mean ± SD

(From Sinaki M, et al. (2005);80(7):849-855)

Prevention of falls and decreasing risk of fracture is important for managing osteoporosis (3). A significant reduction in back pain and risk of falls and improvement in the level of physical activity have been achieved through the SPEED program ($p<0.05$). Subjects who performed the SPEED program decreased their fear of fall and Computerized Dynamic Posturography and gait lab analysis demonstrated reduced risk of falls (Fig 9 and 10), (11).

In summary, as with pharmacotherapy, rehabilitation management is challenging and innovative. To complement pharmacotherapy, individualized osteogenic exercises and rehabilitative measures need to be provided to the patient. Loading exercises are preferred to endurance exercises for improvement of bone mass and reduction of bone loss. Strengthening of axial muscle support can improve mobility in older individuals and decrease kyphosis and risk of vertebral fractures. Studies have shown that even if exercise does not increase bone mass, it can still be beneficial for reducing vertebral fracture, improving dysequilibrium and decreasing the risk of falls and appendicular fractures.

References

1. Sinaki M. Postmenopausal spinal osteoporosis: physical therapy and rehabilitation principles. Mayo Clin Proc. 57:699-703, 1982.
2. Sinaki M. Nonpharmacologic interventions: Exercise, fall prevention, and role of physical medicine. Osteoporosis: Clinics in Geriatric Medicine. Ethel S. Siris, M.D., Guest Editor. W. B. Saunders Company. 19(2):337-359. May 2003.
3. Sinaki M. Falls, fractures and hip pads. Current Osteoporosis Report. Vol 2, No. 4, December 2004, pp 131-137.
4. Sinaki M, Nwaogwugwu N, Phillips, B, Mokri M. Effect of Gender, Age and Anthropometry on Axial and Appendicular Muscle Strength. Am. J. Phys Med. Rehabil., Am J Phys Med Rehabil, 80(5):330-338, May, 2001.
5. Sinaki M, Limburg PJ, Wollan P, Rogers JW, Murtaugh PA: Correlation of Trunk Muscle Strength with Age in Children 5 - 18 Years. Mayo Clinic Proc. 71(11): 1047-1054, November, 1996.
6. Sinaki M. Prevention and Treatment of Osteoporosis. Chapter 42 IN: Physical Medicine and Rehabilitation, 3rd Edition. R. Braddom, (ed), Elsevier, Philadelphia, PA. Section 4, pp 929-949, 2006.
7. Sinaki M. Relationship of Muscle Strength of Back and Upper Extremity With Level of Physical Activity in Healthy Women. Amer J of Phys Med and Rehab, 68(3):134-138, June, 1989.
8. Sinaki M, Brey R, Hughes C, Larson D, Kaufman K. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. OP Intn'l. (DOI:10:1007/s00198-004-1791-2), November 15, 2004; OP Intn'l, 16(8):1004-1009, August 2005.
9. Sinaki M. Shape and Size of an Osteoporotic Woman. Chapter 37 IN: The Aging Skeleton. C. Rosen, J. Glowacki, and J. Bilezikian, (eds). Academic Pres, San Diego, CA. Pp 441-451, 1999.
10. Sinaki M, Itoi E, Wahner H, Wollan P, Gelczer R, Mullan B, Collins D, Hodgson S. Stronger back muscles reduce the incidence of vertebral fracture: A prospective 10-year follow-up of postmenopausal women. Bone 30(6):836-841, June 2002.

11. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Significant reduction in risk of falls and back pain in osteoporotic-kyphotic women through a spinal proprioceptive extension exercise dynamic (SPEED) program. Mayo Clinic Proc, 80(7):849-855, July 2005.
12. Kaplan RS, Sinaki M, Hameister M: Effect of back supports on back strength in patients with osteoporosis: a pilot study. Mayo Clin Proc 71:235-241, March, 1996.
13. Sinaki M, Mikkelson BA. Postmenopausal spinal osteoporosis: flexion vs. extension exercises. Arch Phys Med Rehab, 65:593-596. October, 1984.
14. Schlaich C, Minne HW, Bruckner T, Wagner G, Gebest HJ, Grunze M, Ziegler R, Leidig-Bruckner G. Reduced pulmonary function in patients with spinal osteoporosis fractures. Osteoporos Int 8:261-267. 1998.
15. Gennari C, Donato A, and Camporeale A. Use of Calcitonin in the Treatment of Bone Pain Associated with Osteoporosis. Calcif Tissue Intn'l (1991), 49(Suppl 2):S9-S13.
16. Sinaki M. Critical appraisal of physical rehabilitation measures after osteoporotic vertebral fracture. OP Intn'l. (DOI:10:1007/s00198 -003-1446-8):774-779. August 7, 2003.
17. Sinaki M. Rehabilitation of Osteoporotic Fractures of the Spine. IN: Physical Medicine and Rehabilitation: Rehabilitation of Fractures. State of the Art Reviews. A. J. Mehta, (ed), Vol. 9, No. 1, February, 1995, Philadelphia. Hanley & Belfus, Inc., pp. 105-123.
18. Sinaki M, Itoi E, Wahner H, Wollan P, Gelzcer R, Mullan B, Collins D, Hodgson S. Stronger back muscles reduce the incidence of vertebral fracture: A prospective 10-year follow-up of postmenopausal women. Bone 30(6):836-841, June 2002.
19. Sinaki M, Grubbs N: Back Strengthening Exercises: Quantitative Evaluation of Their Efficacy in Women Age 49-65 Years. Arch Phys Med Rehab 70:16-20, January, 1989.
20. Sinaki M. The Role of Physical Activity in Bone Health: A New Hypothesis to Reduce Risk of Vertebral Fracture. Sheila A. Dugan, MD and Heidi Prather, DO (guest editors), Consulting Editor, George H. Kraft, MD, MS. Elsevier Inc. IN: Physical Medicine and Rehabilitation Clinics of North America. 18(3):593-60; August 2007.
21. Fehling PC, Alekel L, Clasey J, et al. A comparison of bone mineral densities among female athletes in impact loading and active loading sports. Bone 1995; 17:205.
22. Emslander H, Sinaki M, Muhs JM, Chao, EYS, Wahner HW, Bryant SC, Riggs BL, Eastell R. Bone Mass and Muscle Strength in Female College Athletes (Runners and Swimmers). Mayo Clinic Proc. 73(12):1151-1160, December, 1998.
23. Huntoon EA, Schmidt CK, Sinaki M. Significantly fewer refractures after vertebroplasty in patients who engage in back extensor strengthening exercises. Mayo Clin Proc, January 2008. 83(1):54-57.
24. Kurmen Figueroa DA, Sinaki M. Significant reduction of vertebral fractures: comparison of rehabilitation of osteoporosis program-exercise (ROPE) versus No-ROPE, with or without pharmacotherapy. Abstract W393, J Bone Miner Res. 22(Suppl 1):S1- S582, September 2007.
25. de Lignieres B. Hormone replacement therapy: clinical benefits and side-effects. Maturitas 1996; 23(suppl):S31.
26. Salamone LM, Pressman AR, Seeley DG, et al. Estrogen replacement therapy. A survey of older women's attitudes. Arch Intern Med 1996; 156:1293.