Journal für
# Mineralstoffwechsel
Zeitschrift für Knochen- und Gelenkserkrankungen
Orthopädie · Osteologie · Rheumatologie

**Musculoskeletal Rehabilitation in Patients with Osteoporosis - Rehabilitation of Osteoporosis Program-Exercise (ROPE)**

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*Journal für Mineralstoffwechsel & Muskuloskelettale Erkrankungen*

*2010; 17 (2), 60-65*

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Krause & Pachernegg GmbH · VERLAG für MEDIZIN und WIRTSCHAFT · A-3003 Gablitz

P.b.b. GZ02Z031108M, Verlagspostamt: 3002 Purkersdorf, Erscheinungsort: 3003 Gablitz

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# Musculoskeletal Rehabilitation in Patients with Osteoporosis – Rehabilitation of Osteoporosis Program-Exercise (ROPE)

M. Sinaki

**Kurzfassung: Muskuloskelettale Rehabilitation bei Patienten mit Osteoporose: Das „Rehabilitation of Osteoporosis-Program-Exercise" (ROPE).** Die Verschlechterung der biomechanischen Eigenschaften des Achsenskeletts führt zu vielen Komplikationen. Die Reduktion der Knochenmasse und die osteoporotischen Frakturen stellen uns vor Herausforderungen, die nicht allein durch die medikamentöse Therapie gelöst werden können. Die physikalisch-rehabilitativen Maßnahmen spielen eine Schlüsselrolle nach Frakturen sowie in der Prävention weiterer Frakturen. Reedukation der Muskulatur, Widerstandstraining zur Muskelkräftigung und die Reduktion der Kyphose sind Schlüsselelemente zur Risikoreduktion von Stürzen und Frakturen. Umfassende Programme zur Prävention und zum Management von osteoporotischen Frakturen müssen physikalische Rehabilitationsmaßnahmen beinhalten. Bei Bedarf muss auch ein propriozeptives Training (spinal proprioceptive extension exercise dynamic – [SPEED]) implementiert werden.

**Abstract:** Reduction in the biomechanical competence of the axial skeleton can result in challenging complications. Reduction of bone mass and osteoporotic fractures creates specific challenges that cannot be met with pharmacotherapy alone. Physical rehabilitative measures play a key role after fracture and beyond for preventing further fracture. Muscle reeducation, resistance exercises for strengthening, and reduction of kyphosis are key elements for reducing the risk of falls and further fracture. Global programs for prevention and management of osteoporotic fractures should include physical rehabilitation measures. When needed, the Spinal Proprioceptive Extension Exercise Dynamic (SPEED) Program needs to be implemented. **J Miner Stoffwechs 2010; 17 (2): 60–5.**

## Introduction

The combination of pharmacologic and nonpharmacologic interventions is justifiably fundamental to the management of osteopenia and osteoporosis. The musculoskeletal and psychological benefits that are provided by rehabilitation measures are of great importance for improvement of a patient's musculoskeletal health and quality of life.

Reduction in the biomechanical competence of the axial skeleton can result in challenging complications. Several factors contribute to the postural deformities that occur with aging. The 2 most apparent factors are involutional loss of functional muscle motor units and the greater prevalence of osteoporosis in older age [1]. Musculoskeletal rehabilitation and non-pharmacologic interventions consist of exercise, physical management of pain, orthotics, and gait training. Exercise, as a nonpharmacologic intervention for improving bone mass, has been studied extensively.

Aging and immobility result in loss of muscle. Sarcopenia has more effect on type-II fibers ("fast twitch") than on type-I fibers. This expands the type-I motor neuron units at the expense of type-II fibers [2]. Therefore, with aging, muscle mass becomes smaller and weaker. The consequence of these changes is a decrease in the protective role of muscles in musculoskeletal health. Reduction of muscle strength becomes more challenging for women since they have lower muscle strength than men [3] (Fig. 1). Comparison of back extensor muscle strength, upper and lower extremity muscle strength, in healthy men and women aged 21–89 years, has shown that women's muscle strength is lower than men's muscle strength [3]. Indeed, the back extensor strength of women at different decades ranged from 54–76 % that of men [3]. The discrepancy in back muscle strength between the genders decreased with age. Across the decades, men lost 64 % of back extensor strength and women lost 50 % [3].

"Rehabilitation of Osteoporosis Program Exercise" or ROPE includes sedative physical therapy, exercise for prevention and management of osteoporosis, and application of proper orthotics. Treatment programs for osteoporosis are designed to decrease the rate of bone resorption, improve the biomechanical competence of bone, and decrease immobility. Therefore, the objective of ROPE is to improve the individual's quality of life despite osteoporosis and fragility. The major role of ROPE is to emphasize the significance of the role of muscle strength in musculoskeletal health.

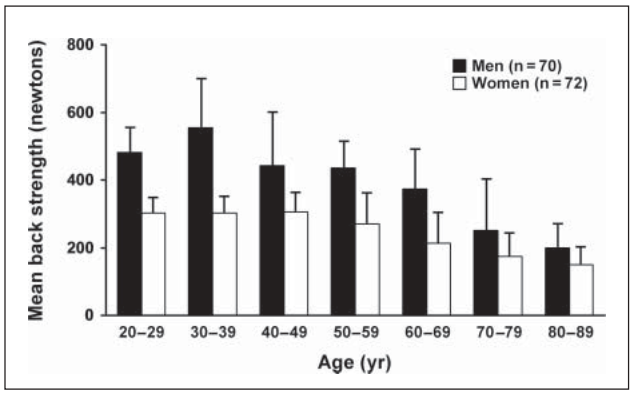


**Figure 1:** Back extensor strength in men and women during the third through ninth decades of life. (From [3] with permission).

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## Rehabilitation Objectives – Why Musculoskeletal Rehabilitation is Necessary in Osteoporosis

The main objective of rehabilitation in osteoporosis is to prevent fractures rather than to treat the complications of fractures. These complications can vary from "silent" compression fractures of vertebral bodies, sacral insufficiency fractures to "breathtaking" fractures of the spine, ribs, or femoral neck [1]. The exponential loss of bone postmenopausally is not accompanied by a parallel incremental loss of muscle strength. Fortunately, the loss of muscle strength follows a more gradual course and is not affected substantially by a sudden hormonal decline, as is bone loss [3] (Fig. 1).

Axial muscle loss can contribute to osteoporosis-related skeletal disfiguration and to an increased incidence of falls. In men and women, the combination of aging and reduction of physical activity can affect musculoskeletal health and contribute to the development of bone fragility and falls (Fig. 2).

Vertebral fractures and kyphotic posture are well-recognized complications of osteoporosis. Musculoskeletal consequences of bone loss and sarcopenia influence skeletal integrity in women more than men, since to start with after adolescent age, women have lower bone mass and muscle strength than men. Improvement of back strength reduces back pain [4] and kyphotic posture [5] that can occur with osteoporosis and aging. Bone loss is substantially greater in women than in men [6]. Skeletal health depends not only on healthy bones but also on strong supportive muscles. The number of muscle fibers decreases 39 % by age 80 [2]. It is a well-accepted fact that muscle and bone loss occur with aging. The loss of axial muscle and the correlation with musculoskeletal changes, however, have not been adequately addressed in the previous literature. Therefore, further studies are needed to define the contribution of muscles to maintenance of musculoskeletal integrity. Musculoskeletal complications can be reduced with maintenance of muscle strength. Stronger back muscles are correlated with fewer vertebral fractures [7, 8] and lesser thoracic kyphosis [5]. Stronger lower extremity muscles can decrease risk of fractures in the lower extremities [9]. Bone loss is more significant in the axial skeleton than in the appendicular skeleton. There is a disproportionate loss of axial trabecular bone, approximately 47 %, throughout a woman's life;

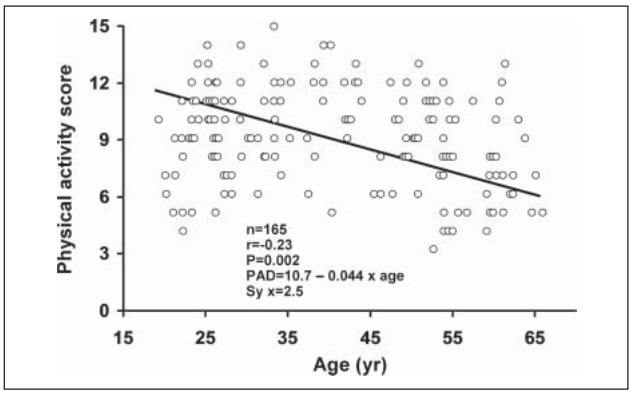


**Figure 2:** Relationship between physical activity score (PAS) and age in 165 subjects between 19 and 66 years of age. (From [1] with permission.)

whereas, in men this loss is approximately 30 %. The loss of bone density in the appendicular skeleton is approximately 30 % in women and about 15 % in men [10]. Therefore, measures to decrease age-related loss of muscle strength become even more important for maintaining women's skeletal health.

Frost's hypothesis of minimal effective strain stimulus indicates that muscular contraction and mechanical loading are needed to maintain healthy bones [11]. Therefore, weight-bearing exercises are superior to weight-supportive exercises such as swimming. Aging has been correlated with reduction of physical activity [12] (Fig. 2). Concomitant reduction of physiologic muscle strength with bone loss can increase the risk of fractures. In osteoporosis, safe straining of musculoskeletal structures with proper physical activities can reduce the risk of immobility-related deconditioning.

## General Rehabilitation Recommendations

Before prescribing a rehabilitation program, information needs to be obtained on current medical status, nutritional status, and medication use. In addition, we need to consider the patient's physical, functional, psychological, and social status and limitations. We need to understand and practice the general principles of therapeutic exercise defined in the "Osteoporosis Rehabilitation Guidelines" [13] which have been developed on the basis of the earlier evidence-based studies and literature.

Rehabilitation training includes evaluation for the performance of safe locomotion and activities of daily living, including transfers, lifting, and ambulation in populations with or at high risk for osteoporosis and fractures. A life-long physical activity and exercise lifestyle, starting in childhood, helps to build the highest possible bone mass and reduce the challenges of bone loss later in life. Also, stronger back and high level of physical activity in childhood can decrease risk of back pain [14, 15]. As long as principles of safe movement are followed, walking and daily activities, such as housework and gardening, are practical ways to maintain fitness and bone mass in older populations and people of any age [13].

In cases of rehabilitation of the fragile skeleton, progressive resistance training and increased loading exercises, within the biomechanical competence of the individual's current musculoskeletal health status, are beneficial for muscle, bone, and ligamentous strength. Improving disequilibrium and strengthening hip girdle muscles and quadriceps to allow a person to rise unassisted from bed or chair and negotiate stairs are necessary. These types of exercises can contribute to maintaining independence. When needed, the "Spinal Proprioceptive Extension Exercise Dynamic" (SPEED) Program needs to be implemented [16].

In general, depending upon the baseline evaluation of the patient's musculoskeletal status, provision of a complete exercise program would include weight-bearing aerobic activities for cardiovascular fitness, postural training, progressive resistance training for axial muscle and bone strengthening, stretching for tight soft tissues and joints (Fig. 3) and balance training to prevent falls [16].

Proper exercise in individuals, with or without vertebral compression fracture, would improve function, could prevent immobility-related loss of bone, muscle strength, postural instability, and risk of falling. Appropriate pharmacotherapy and nutritional guidance along with the exercise and other rehabilitative measures would improve quality of life and longevity. In acute vertebral fractures or chronic pain after multiple vertebral fractures, the use of a trunk will provide pain relief by reducing the loads on the fracture sites through better alignment of spine. Long-term bracings may lead to muscle weakness and further deconditioning and are discouraged [17].

Early intervention for pain management would prevent development of chronic pain syndrome and is the basic concept in rehabilitation of post vertebral fractures. Pain relief may be achieved through early, but limited, use of orthotics, sedative physical therapy (i.e, heat/cold, stroking massage), and analgesics. Behavioral modification techniques can also be used with consideration that the benefit of pain relief should not outweigh the risk of side-effects such as disorientation or over-sedation which may result in falls. If pain persists after vertebral fractures, despite conservative management, analgesic patches may be applied to the paraspinal areas along with implementation of easy postural exercises.

Kyphoplasty or vertebroplasty, in some cases of refractory pain, can be helpful when performed by experienced practitioners and needs to be combined with rehabilitation meas-

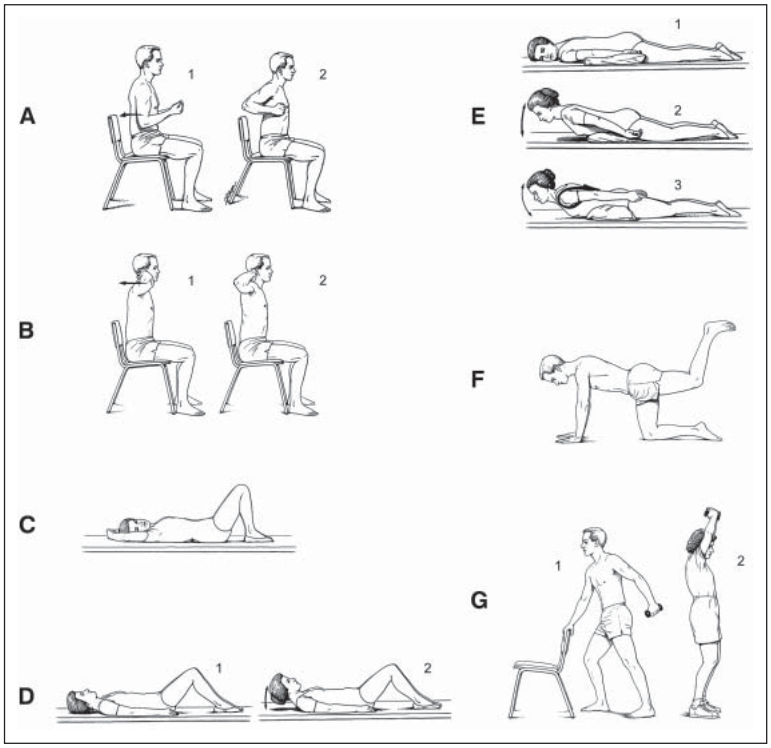


**Figure 3:** Several back extensor exercises of ROPE program developed for the osteopenic/osteoporotic spine – with or without use of weights. By Sinaki M. through a grant from the "Retirement Research Foundation". (Reprinted with permission from the Mayo Foundation).

ures. One study showed that if kyphoplasty or vertebroplasty is not combined with ROPE, there will be a higher incidence of vertebral fracture [18].

Hip protectors may reduce the occurrence of hip fractures in elderly individuals at high risk for falls such as history of previous falls or impaired balance and vision; however, compliance for their regular use needs to be advocated [19].

Fragility and falls are malignant combinations with disastrous results. Falls among the elderly, especially those with osteoporosis, are associated with high morbidity and mortality and can involve high-cost medical interventions. Evaluation of the risk of falls in persons with osteoporosis is of high priority for both research and clinical interventions. Disequilibrium and body sway can be important risk factors for falls in the elderly with osteoporosis [20].

Postural stability and balance decrease with age. After age 60, one out of 10 people fall and some of these falls result in injury [21–23]. In one study, most falls during computerized balance testing occurred in subjects older than 50 years. Furthermore, the amount of body sway increased with age. The flexed posturing that often develops in elderly people places their center of gravity closer to their limits of stability [24, 25]. This change also is expected in subjects with kyphosis caused by osteoporosis [22, 23]. Therefore, measures that can improve axial stability can decrease disequilibrium as in SPEED program [16].

## Vertebral Compression Fractures

The basic general principle for non-pharmacotherapy and rehabilitation after fracture is to decrease pain and facilitate mobilization as quickly as possible after the fractured area is stabilized. The main objective of physical management is to eliminate pain-induced reflex inhibition. Spinal compression fracture and pain can produce an imbalance between the use of back extensors (the major trunk supportive muscles) and flexors [1]. The pain-induced inhibition results in overuse of spinal flexors that will further contribute to hyperkyphosis. Therefore, it is necessary to relieve pain through proper bracing of the spine and reduction of edema in the soft tissues surrounding the fractured area. Spinal orthotics can vary from rigid bracing to weighted support as in SPEED program [16]. The choice of orthotic depends on the patient's status of musculoskeletal need. Rigid braces are undesirable and their use should be limited. Back supports that promote muscle re-education are preferable.

Cryotherapy has been proven beneficial in the management of posttraumatic edema [26, 27] and is commonly prescribed at the acute stage of vertebral fracture. The result of vertebral wedging and compression fracture is increased thoracic hyperkyphosis. Compression fractures occur most often at the mid thoracic and upper lumbar spine, followed by the lower thoracic and lower lumbar spine, and rarely in the upper thoracic spine [28]. To decrease painful contractions of the erector spinae muscles, one needs to decrease the load over the anterior aspect of the spinal column and vertebral bodies through use of a weighted kypho-orthosis positioned below the inferior angles of the scapulae [29, 30].

Exercise is known to contribute to general good health; however, osteogenicity requires specific exercises. Callisthenics have not contributed to reduction of risk of fractures [31]. Therapeutic exercise plays a substantial role in the management of post-fracture spinal pain [4, 32] and in the prevention of further fracture [8, 9]. The mechanism by which exercise decreases pain is not totally understood. In a randomized 10-year follow-up study, improved axial muscle strength in the resistance exercise group was associated with a significant reduction of spinal bone loss ($p = 0.0004$) and incidence of vertebral fractures ($p = 0.02$) [8] (Fig. 4). In the first 2 years of the same study, the back strength of the subjects (control and exercise groups) was measured every 4 weeks. The exercise group performed specific back extension exercises through weight lifting on their backs for 2 years [33]. The long-term effect of back resistance training on the spine after its cessation was reported in a controlled, randomized, 10-year follow-up study of estrogen-deficient women [8]. The relative risk of compression fracture was 2.7 times greater in the control group than in the back exercise group [8] (Fig. 4).

Back exercise programs are prescribed according to the status of the individual's musculoskeletal health. Individuals with osteoporosis have been shown to have lower back extensor strength than healthy women [34, 35]. Back extension exercise for the fragile spine can be initiated in the sitting position and later advanced to back extension in the prone position [28, 32]. Specific exercises are recommended for the spine with osteopenia, osteoporosis, and severe osteoporosis. Back extension in a sitting position is safe for new vertebral compression fracture; however, the implementation needs some innovative interventions.

## Kyphotic Posture is a Great Concern

Kyphotic malposture can increase risk of vertebral wedging and fracture, increase back pain and risk of fall, and reduce

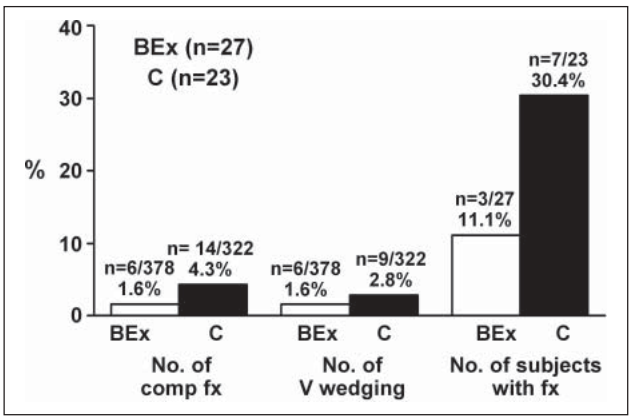


**Figure 4:** At 10-year follow-up, the number of vertebral compression fractures (comp fx) was 14 in 322 vertebral bodies examined (4.3 %) in the controls (C) and 6 fractures in 378 vertebral bodies examined (1.6 % in the back exercise [BEx] group [$\chi^2$ test, $p = 0.0290$]). The number of controls with vertebral fractures was 3 times greater than BEx group. (With kind permission from Springer Science + Business Media: [Sinaki M. Critical Appraisal of Physical Rehabilitation Measures After Osteoporotic Vertebral Fracture. Osteoporosis Int 2003; 14: 774–9]).

participation in physical activities due to fear of falls and back fatigue [16]. Furthermore, kyphosis can contribute to disequilibrium. Receptors in muscles, tendons, joints, ligaments and skin all play a role in proprioceptive input [36]. Therefore, joint position sense is fundamental to posture, balance, and locomotion. Postfracture pain-induced reflex inhibition and vertebral deformity can interfere with the kinesiology of the spine and proper recruitment of paraspinal muscles for support of the spine. Therefore, muscle reeducation through biofeedback techniques is important to improve synchronized muscle contraction during movement of functional units of the spine.

One study reported that body sway was an independent predictor of fracture prevalence in 1479 subjects and concluded that determination of balance was important to the prediction of falls and fracture [37]. Another study showed increased risk of fall with kyphosis [23].

In the SPEED study [16], all subjects had baseline assessment of their level of pain (scale of 0–10, with 0 being no pain), muscle strength, level of physical activity, fear of falls, computerized dynamic posturography (CDP), and equilibrium-risk of falls (evaluated at gait lab). Subjects kept a daily diary of their pain level during the 4-week study and were monitored at 2 weeks to assess their level of physical activity to make sure they were following the prescribed exercise program but not adding any additional strenuous activities. At the end of 4 weeks, each subject's back pain, physical activity score, CDP, gait, and muscle strength measurements were again evaluated. CDP assesses both sensory organization and motor control components of balance. CDP is a safe, noninvasive procedure that takes approximately 20 minutes to perform [38]. All parameters showed significant improvement – equilibrium, risk of falls at obstacles, fear of falls, back pain, and level of physical activity (Fig. 5). Body height also improved but not significantly. Since the most disfiguring effect of osteoporosis is on the spine, combining proper back extension exercises [33] with SPEED will have the most favorable result. As reflected in our most recent hypothesis [39], back resistive exercises from prone position would improve vertebral horizontal trabeculae, which can decrease risk of vertical loading of osteoporotic spine and potential vertebral fracture.

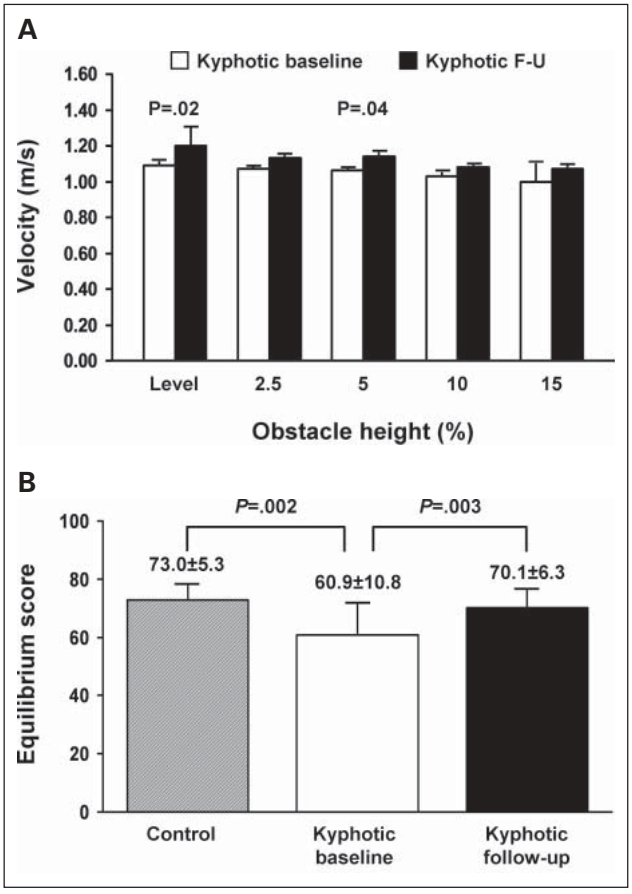


**Figure 5: (A)** Anteroposterior velocity in subjects with osteoporosis-kyphosis at baseline and follow-up. After a 4-week trial of a spinal proprioceptive extension exercise dynamic (SPEED) program and spinal weighted kypho-orthosis, level walking and 5 % obstacle walking improved. Error bars = 1 SD. **(B)** Composite Equilibrium Score of Computerized Dynamic Posturography in Control Subjects and Subjects With Osteoporosis-Kyphosis at Baseline and Follow-up. Equilibrium of the kyphotic subjects improved significantly after a 4-week trial of a spinal proprioceptive extension exercise dynamic program and spinal weighted kypho-orthosis. Data are reported as mean (SD). A score ≥ 68 is normal for a person aged ≥ 60 years. (Adapted from Sinaki et al [16]. Used with permission).

## Conclusion

Reduction of bone mass and osteoporotic fractures creates specific challenges that cannot be met with pharmacotherapy alone. Physical rehabilitative measures play a key role after fracture and beyond for preventing further fracture. Muscle reeducation, resistance exercises for strengthening, and reduction of kyphosis are key elements for reducing the risk of falls and further fracture. Global programs for prevention and management of osteoporotic fractures should include physical rehabilitation measures. In the long term, critical evaluation of rehabilitation measures can be very economical if the unnecessary use of rigid bracing, gait aids, and wheelchairs is reduced significantly. In addition, reducing immobility can save lives since proper mobility can decrease further bone loss and prevent deep venous thrombosis, pulmonary infection, or even death. There is a dearth of controlled trials in this area, perhaps due to lack of funding for non-pharmacologic research.

In a retrospective study of women with the diagnosis of osteoporosis, the efficacy of a defined exercise program (ROPE) was assessed for management of osteoporosis. The subjects had been divided into groups with or without pharmacotherapy and with or without ROPE. The outcome was based on the incidence of new vertebral compression fractures. On follow up, the incidence of fracture in the No-ROPE group was greater, despite pharmacotherapy ($p = 0.001$, Pearson $\chi^2$ test) [40]. Thus, ROPE is necessary for management of osteoporosis, regardless of choice of pharmacotherapy. More studies are needed to address rehabilitation interventions. Further studies investigating post fracture muscle strengthening techniques, reduction of kyphosis, and prevention of falls will help to support our conviction that non-pharmacological rehabilitative management of osteoporosis, when properly utilized, is beneficial and cost-effective. Physical rehabilitative measures play a key role after fracture and beyond for preventing further fracture. Muscle reeducation, resistance exercises for strength-

ening, and reduction of kyphosis are key elements for reducing the risk of falls and further fracture.

## Acknowledgment:

The author thanks Ms. Sandra Fitzgerald for her excellent secretarial support.

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