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Rehabilitation in Osteoporosis

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1. Introduction

Osteoporosis is a metabolic bone disease usually occurring with increasing age and is defined as a skeletal disorder characterized by reduced bone mineral density and strength. Osteoporosis is characterized as the “silent disease” because is painless until the first occurrence of a fracture and thus remain unnoticed. The first symptom of osteoporosis is the bone fracture with a preference of distal radius or proximal humerus fracture, vertebral collapse and femoral neck fractures beyond the 50th, 60th and 70-75th year respectively (Pfeifer et al., 2005). This phase of the disease is characterized by acute pain. Moreover, vertebral fractures cause acute musculoskeletal pain in the back in the acute phase of the fracture and chronic pain resulting from the associated skeletal deformity, joint incongruity, and tension on muscles and tendons, leading to disability. In generally osteoporosis represents one of the main causes of back pain in postmenopausal women because of common clinical or subclinical vertebral fractures causing back pain. On the other hand, in the same population, no osteoporotic vertebral deformities are seen as often as osteoporotic ones, and back pain was found to be mostly due to degenerative disorders of the spine in women above 60 years (Dionyssiotis, 2010b).

Osteoporosis is a disease that predominantly affects postmenopausal women and older people although in individual cases could concern people in younger age i.e. in the juvenile form, mainly men with idiopathic osteoporosis, pregnancy-associated osteoporosis, the form of secondary osteoporosis in young steroid-treated patients with chronic inflammatory diseases etc. The goals of rehabilitation are changing depending on the stage of disease. In the acute phase of a vertebral body collapse the therapy is to the relief pain by a limited period of bed rest, local and systemic analgesia, bracing, physical therapy, education with proper exercises and instructions according to daily living activities in order to mobilise the patient with safety. Rehabilitation after surgical stabilization of a hip fracture is crucial in order to optimize post-injury mobility and the functional recovery of the patient, restore pre-fracture function and avoid long-term institutionalization. Most evidence-based guidelines suggesting possible treatments and rehabilitation pathways for hip fracture patients, agree that it would be best if they underwent multidisciplinary rehabilitation (Dionyssiotis et al., 2008a).

In prevention and management of osteoporosis modern rehabilitation medicine should not only focus on bone ignoring muscular strength and balance. These elements are directly related to the disease offering protection against predisposing a person to an increased risk of falls and fall-related fracture. An extensive research in the area of pharmacological

treatment is ongoing. Pharmacologic treatment increases bone strength, but has no effect in muscle strengthening or balance. Moreover beyond drugs there are other interventions often overlooked: supplementation with calcium, exercise programs, orthoses, vitamin D, and fall prevention.

2. Calcium, vitamin D and vitamin D analogues

All of the studies on the effectiveness of anti-osteoporotic drugs required the taking of calcium and vitamin D and recent findings reveal a decreased effectiveness of therapy in individuals with low levels of vitamin D during the therapy (Nieves et al., 1998; Koster et al., 1996; Adami et al., 2009). Trials reporting bone-mineral density, calcium and calcium in combination with vitamin D were associated with a reduced bone loss at the hip and in the spine. A positive treatment effect on bone-mineral density was evident in most studies (Tang et al., 2007). In opposition to findings on the use of calcium and vitamin D together, studies which researched the relative role calcium or vitamin D separately, produced conflicting results. Moreover, calcium and vitamin D or vitamin D by itself increase muscular strength and decrease the number of falls Bischoff-Ferrari, et al., 2006; Bischoff et al., 2003).

Pooled data comparing vitamin D alone with placebo or no treatment showed no statistically significant effect on vertebral fracture or deformity. Vitamin D (including 25-hydroxy vitamin D) with calcium was no more effective than calcium alone on vertebral fracture. Evidence has shown that vitamin D alone was less effective than calcium for the prevention of vertebral fracture or deformity. There was no evidence of a statistically significant preventive effect on clinical vertebral fractures from the administration of vitamin D and calcium and vitamin D plus calcium versus placebo or no treatment. In participants with osteoporosis no statistically significant effect of alfacalcidol (1-alpha-hydroxy vitamin D3) compared with vitamin D and calcium on people with new vertebral deformities was found. Calcitriol (1,25 dihydroxy vitamin D3) and additional supplementation with calcitriol in people with osteoporosis already taking calcium had no statistically significant effect on new vertebral deformity. No statistically significant effect on the number of people developing new vertebral deformities receiving calcitriol plus vitamin D and calcium versus vitamin D and calcium was found. Overall, there was no statistically significant effect on the incidence of vertebral deformities with calcitriol versus calcium. When calcitriol was compared with vitamin D in people with pre-existing osteoporosis no statistically significant effect was seen for vertebral deformities (Avenell et al., 2009).

3. Exercise in osteoporosis

3.1 Biomechanics and mechanobiology of bone

One useful introduction to understanding the response of bone in physical activity is to understand bone's morphology and mechanical properties (Dionyssiotis, 2008b). Bone is a unique material, within the functional structure of the skeleton, which is strong enough to withstand the demands of intense physical activity and external forces exerted, adjusted to changes in those requirements, and light in weight to allow efficient movement and energy saving. The mechanical capacity of bone is a function of internal properties of material (mass, density, stiffness, strength) and geometrical characteristics (size, shape, thickness of cortical cross-sectional area and architecture of trabeculae). The peripheral bone adapts to mechanical loading through endosteal resorption and periosteal apposition of bone tissue

(Figure 1) (van der Meulen, 1993). This increases the diameter of the bone and therefore provides greater resistance to the loads. This adaptive process allows the bone to resist in compression, tension and shear forces, but also to be light enough for efficient and economical movement (Wolff,1870).



Fig. 1. An increase in bone dimensions during development and the gradual age-related endosteal resorption, periosteal apposition and cortical thinning. The increase in bone strength because of the increase in diameter replaces the loss of density (adapted, modified and translated with permission from Dionyssiotis, 2008b).

According to Wolff's law bone will optimize its structure, to withstand the functional burden and to ensure the metabolic efficiency of movement (Wolff, 1892). The loading of the skeleton is described as a strain that produces the modified response of bone to loading. It has been suggested that the osteocyte reacts-perceives the strain and transmits signals to osteoblasts to build bone. The magnitude of strain can be defined as the amount of relative change in length of the bone under mechanical loading (Beck et al., 2001). Mechanical stimulation generated by exercising has at least two opposite effects on bone. The bone as a material is weakened by repeated strains, causing minor damages on bone structure; on the other side, stress strain which exceeds a certain threshold leads to generation and thereby adjusts the strength of the bone load usually applied (Wolff, 1870). This is a feedback cycle, which is usually called as the mechanostat (Frost, 1987a).

The mechanostat theory describes a system in which a minimum effective strain (MES) is essential for maintaining bone (Frost, 1987b). In the overload zone of the system (2000–3000 micro strain) bone is stimulated and new bone is added in response to mechanical requirement. This leads to increased bone strength. Finally, in the pathological overload zone (>4000 micro strain), a minor damage of bone is present and bone mineral is added as part of the repair process. A sufficient number of studies suggest the ability of estrogen to alter the set point of bone strain in responses to mechanical loading as the result of indirect effect of oestrogen' receptors number (Lanyon & Skerry, 2001; Lee & Lanyon, 2004). The decrease in sensitivity of oestrogen receptors as a result of oestrogen deficiency may reduce the response of bone to mechanical loading (Cheng et al., 2002; Jessop et al., 1995). Strain of about 1.000 micro strain increases bone formation, in the presence but not in the absence of oestrogen. Loading forces in the skeleton are caused by gravity (weight bearing), muscles and other external factors.

3.2 Targeted exercise for osteoporosis

Physical activity targeting muscles and balance is the cornerstone of each rehabilitation program for osteoporosis and fracture prevention. Although, in postmenopausal individuals, results of physical activity studies on the positive association of physical activity with bone status are conflicting (Burger et al., 1998; Nguyen et al., 1998). However, it is clear that physical activity is vital in adults (Kelley, 1998; Beitz & Doren, 2004) because it reduces the rate of bone loss during the peri-menopausal period, and decelerates bone loss associated with aging (Asikainen et al., 2004).

In the design of an exercise program to increase bone mass we need to take in mind the following five principles (Drinkwater, 1994) 1. Specificity: The program must be designed to load specific bones or body regions, 2. Overload: To induce stimulation for increasing bone density according to mechanostat theory exercise must overload the bone, 3. Reversibility: In adults, any gains in bone density during an exercise program will be lost if the program stops. However, in children and adolescents the benefits achieved by increased mechanical loading during exercise program remain even if the exercise program stops, 4. Initial Values: The response of bone to increased loading is greater when bone mass is below average. Patients with bone mass below normal will experience greater gains in bone density with exercise programmes, compared with people who have a good bone density, 5. Diminishing Returns: The greatest gains in bone density will be seen early in an exercise program. After the initial increase, the benefits continue but at a slower pace. We added the 6th principle of Variety which is a component of success in all exercise programs. We need to enrich the programs with various exercises and not perform the same exercises, at the same duration and interval. By changing the way of bone and muscle stimulation we challenge them in new way shifting the loading stress causing new results (Dionyssiotis, 2008b).

To summarize the principles: Not all types of physical activities that provide bone loading to the skeleton produce bone mass benefits. Some activities (i.e. a progressive jogging program) charge and stimulate adaptation of the cardiovascular system, but do not stimulate an adaptive bone response that would increase bone density (Khan et al., 2001). The bone has a lazy zone! Each exercise that stimulates the metabolism in the body (i.e. exercise for the cardiovascular system etc.), is not able to stimulate the adaptation of bone to increase bone density. The load on a bone during the exercise should be substantially greater than the load experiencing of the bone during activities of daily living. There is definitely a threshold load which must be reached to generate gains in bone mass. Moreover, loading of the bone should be done in such a way that mimics the physical loads (Skerry, 1997).

There are also activities that provide bone loading at one site of the body, but not at other sites. The osteogenic effects of exercise should be specific to the anatomical sites where the mechanical strain occurs (Lohman et al., 1995). The most common types of physical activities (e.g., gardening, swimming) use many muscles but do not involve targeted bone loading, and therefore do not produce loads heavy enough to exceed the load threshold on bones achieved by usual daily activities (Beck & Snow, 2003; Madalozzo & Snow, 2000). The duration of the physical activity is also important; up to 2 hours per week is considered to positively affect bone mass maintenance (Snow-Harter & Marcus, 1991). Muscle strengthening, weight bearing combined with flexibility, posture control, balance, coordination and training in daily living activities to improve functional capabilities of the subjects should be part of a rehabilitation program in osteoporosis. The following subchapters explain basic exercises of each category (except balance and coordination exercises which will be analyzed in the subchapter of falls prevention) in detail.

3.2.1 Muscle strengthening exercises

In osteoporosis we do not recommend muscle strengthening in generally. Programs are focused on specific regions of the skeleton where fractures are most commonly expected, namely the spine, the hip and the wrist. For this reason in all ages, but particularly in postmenopausal women, exercise programs focusing on muscles in these regions (Table 1) including exercises for the back muscles, the hip and the hand (with weights or pulleys) but also for the thighs because research has shown that the quadriceps is an important muscle for balance and falls prevention.

Type Muscle strengthening	Target	Intensity Frequency Duration	Time to target	Contradictions
Using body weight, free weights, elastic bands, sophisticated equipment in the gym etc.	Increasing strength, stimulate bone to increase bone density (targets are mostly hip muscles, back muscles, biceps, triceps)	8-10 repetitions 2 sets 2-3 times weekly 20-30 minutes	6 months for bone mineral density changes	Subjects with kyphosis should avoid bending and turning the spine and perform the exercises seated

Table 1. Muscle strengthening exercises in osteoporosis; the table summarises the following characteristics of this type of exercise: how we can do them, which are the targets, the intensity, frequency and duration of the program, when to expect the results and the contradictions (Dionyssiotis Y. , 2010 c).



Fig. 2. (1 to 6) *Back muscles*: This group of muscles is usually underestimated in exercise programs, but it requires special attention. The subject should begin warm up in the prone position with the hands flat on the ground and the elbows facing outwards and hold for one minute (photo 1), then raise the head keeping this position for five seconds (photo 2), then return to the starting position. The exercise needs to be repeated five times. The simplest style is photo 3: from the prone position to raise only the hands, with the elbows bent at 90 degrees, whereas it becomes more difficult when the arms are placed at the side of the body and the head is gently raised (photos 4, 5). The exercise needs 15 repetitions 6 times per day (3 in the morning - 3 in the evening). As strength increases it is possible to do more difficult exercises; from a kneeling position, extend one arm and raise the opposite leg. This exercise should be repeated ten times every day. (Dionyssiotis Y., 2010 c).



Fig. 3. *Resistance against a wall (such as push-ups)*: The subject stands opposite a wall and place the hands against the wall with the palms flat on the wall. The feet are spread 15 cm apart. In the next step the subject presses against the wall with the elbows bent and then returns to the initial position. This exercise needs 20 repetitions 3 times per day (Dionyssiotis Y., 2010 c).

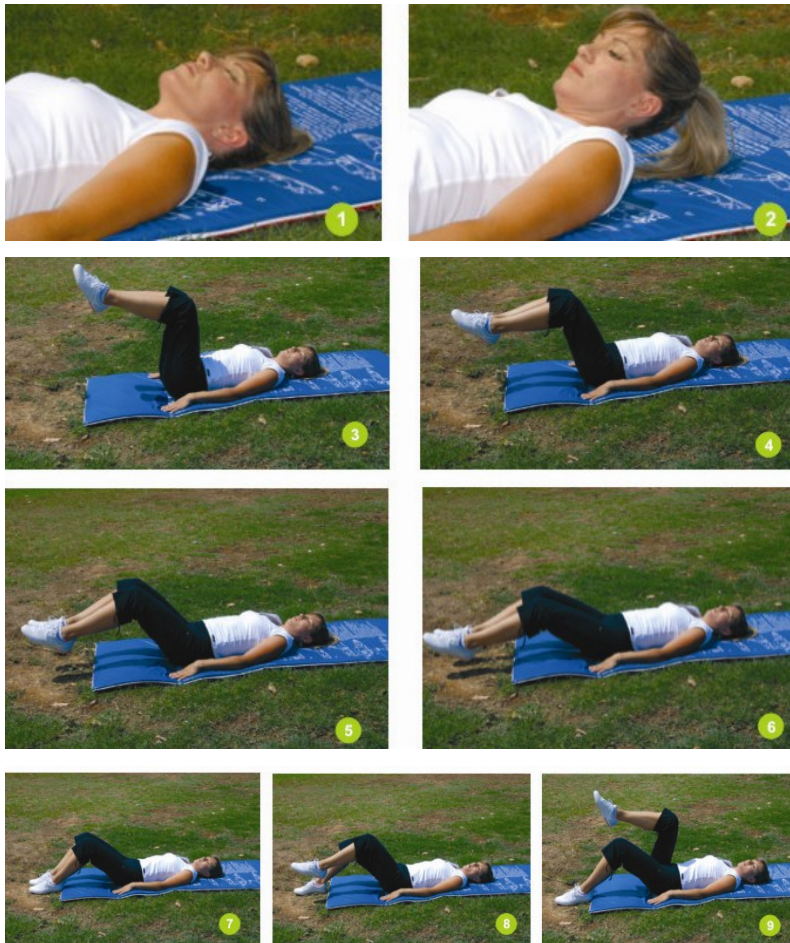




Fig. 4. *Abdominal muscles strengthening*: The subject should begin warm up in the supine position, bringing the chin to the chest for five to ten repetitions (photos 1, 2). The safest exercise for abdominal muscle strengthening includes performing from the supine position with the back flat on the ground, the legs raised and the knees bent at ninety degrees (photo 3). The knees are then extended while lowering the legs with movement coming from the hip joint (photos 4, 5, 6). The spine must be flat on the ground while this exercise is performed. If it is not possible to perform the total movement of this exercise, it should be performed in the half of range as shown in photograph 4. If this exercise causes pain, the subject should alter it as follows: with the legs bent and the sole of the foot on the ground, bend one leg to the abdominals then lower the leg to the ground and the same movement with the other leg (photos 7, 8, 9). Another option is to raise the head with the arms extended to touch the knees (photo 10), (Dionyssiotis Y., 2010 c).



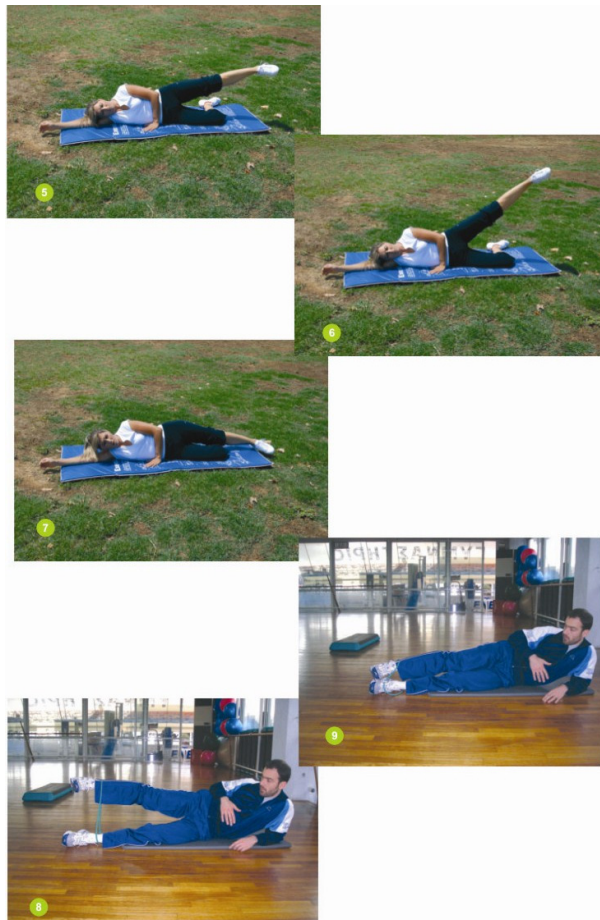


Fig. 5. *Extensor and abductor muscles of the hips*: The subject places the hand on a fixed spot for safety (i.e: chair photo 1) and lift one leg backwards in order to exercise the gluteus maximus muscle extensor muscle (photo 2). Then the movement is repeated with the other leg. From the same position lifts one leg to the side, in order to strengthen the gluteus medius muscle abductor muscle (photo 3); then the other leg follows. For each leg three sets of 15 repetitions are needed. Both exercises can be done with pulleys (at home or at the gym), lying sideways on the ground and also with specific equipment at the gym under the guidance of a qualified instructor (see photos 5-9). Keeping good technique during this exercise is very important and four sets of fifteen repetitions are necessary (Dionyssiotis Y., 2010 c).



Fig. 6. *Quadriceps*: The subject sits upright in a chair with the back as straight as possible, the knees bent and the feet flat on the ground (a chair with armrest is recommended), grips the chair firmly and extends one knee at a time keeping it extended for 4 seconds. This exercise is particularly indicated for elderly people and after hip surgery. The exercise can be done with pulleys and with special equipment in the gym. Each leg needs fifteen repetitions (Dionyssiotis Y., 2010 c).



Fig. 7. *Exercises with dumbbells for the arms*: Exercises for strengthening the biceps and triceps can be done from a standing or seated position. From a standing position the subject flexes the knees slightly, and using medium weights performs three sets of 10 repetitions with each arm (photos 1, 2, 3). Weights can be replaced with pulleys for lower resistance (Dionyssiotis Y., 2010 c).

Subjects need to perform the exercise as above with the same number of repetitions remembering to maintain the correct posture while exercising. For additional safety, exercises should be performed in a seated position by patients with severe osteoporosis.

3.2.2 Weight bearing exercises

Weight bearing exercises are exercises during which the weight of the body passes through the bones. Examples of these types of exercises are walking, jogging, dancing, gardening, tennis, football, basketball and trampoline etc. There is a variety of this type of exercise to suit every age group. The impact to the bone during this exercise should be higher than that during normal everyday activities. Many women believe that housework and the level of

activity it involves constitutes a good level of exercise. However, this is not correct as in order for exercises to be effective they need to be performed with specific technique and systematically.

Type Weight bearing	Target	Intensity requecy Duration	Time to target	Contradictions
Walking, jogging, dancing, gardening, tennis, basketball etc.	Maintenance of bone mass Improvement in physical function	40-70% max. Power 3-5 times/ week 20-30 min	9-12 months to improve BMD	Bending and turning in patients with osteopenia

Table 2. Weight bearing exercises; the table summarises the following characteristics of this type of exercise: how we can do them, which are the targets, the intensity, frequency and duration of the program, when to expect the results and the contradictions (Dionyssiotis Y., 2010 c)



Fig. 8. *Walking*: Dynamic walking is the best option for prevention of osteoporosis. Simple walking is not enough; it should be in an open environment without obstacles, not around the house or workplace. Dynamic walking differs from regular walking and to achieve maximum benefit to the skeleton a special technique is required. Brisk walking (dynamic walking) does not require any special equipment except for a good pair of training shoes. Moreover it has the advantage of low risk of injury. Walking should begin at a normal pace, progressively increasing after five minutes to a medium and then to a fast pace for twenty minutes. The pace must be sufficient to allow normal speech but not so fast that the person is out of breath. The level of intensity however should be sufficient for the person to sweat. In order to move the feet faster it is necessary to move the hands faster. Arms should move in the opposite direction to the feet. During the movement of the hands, the subject need to flex the elbows and keep the arms close to the body. Attention should be paid to change of pace, using bigger steps and the feet should be kept in a forward facing direction and not sideway. This kind of walking should be done as often as possible (Dionyssiotis Y., 2010 c).



Fig. 9. *Dancing* as exercise is safe and social which in turn makes this an attractive activity. Jumps and aerobic weight bearing exercises during dancing or gymnastics are related to increasing and maintaining bone density. Traditional Greek dances include movement like jumps, sideways steps and squatting which have a weight bearing effect on the hip and spine (Dionyssiotis Y., 2010 c).

3.2.3 Postural exercises

The aim of these exercises is to: Eliminate the bent-over position (hunchback), which increases the pressure on the front part of the vertebrae and to improve stability. Exercises can be done in the sitting or standing position with eyes open or closed. The optimal is to be performed in front of a mirror and next to a wall. The reason why the exercises are performed in front of a mirror is that the trainees can see their reflection and can correct the possible mistakes in their posture, with the guidance of the experts (visual biofeedback). The wall assists the safe performance of the exercises.



Fig. 10. *Exercises in patients with osteoporosis for correction of posture: Decompression of the spine:* the exercise starts lying on the ground with the knees bent, the feet flat on the ground, the elbow bent and the palms facing upwards and this position is kept for five minutes. This exercise decompresses the spine and relieves back pain. *Shoulder press:* beginning from the same position, the shoulders are pressed to the ground holding for three seconds, and then the subject relaxes himself and repeats three times. This exercise strengthens the muscles of the upper back. *Leg press:* beginning with the position of exercise 1) above, the subjects extends one leg with foot pointing upwards, presses the full length of the leg into the ground, concentrates for 2-3 seconds and relaxes himself. The same steps are performed with the other leg (4 repetitions with each leg). This exercise helps with posture and strengthens the extensor muscles of the thigh (Dionyssiotis Y., 2010 c).

3.2.4 Flexibility exercises

During aging the body becomes more rigid which results in movement difficulties leading to falls and increasing risk of fracture. For this reason it is necessary to perform exercises to maintain flexibility. The exercises in this category help to maintain the elasticity and the length of the muscle, the range of movement of the joints, improve posture and reduce pain (mostly back pain etc).



Fig. 11. *Stretching the pectoralis major (stretching of the chest)*: From the standing or sitting position (for greater safety), with the arms bent at the elbows and to the side of the torso, the subject moves the elbows backwards (photo 1). The arms can also be raised in front of the chest with the elbows bent up to the height of the shoulders (photo 2) and then spreads open the arms stretching them out (photo 3). The exercise should be performed daily with 10 repetitions, 3 times (Dionyssiots Y., 2010 c).



Fig. 12. *Stretching the upper torso*: In this exercise the subject stands or sits on a comfortable chair, the fingers are placed behind ears, palms facing forwards and elbows pointing outwards (photo 1). Stretching the chest by pushing the elbows backwards (without pressing the head) is followed holding this position for 4 seconds and then bringing the elbows together, in front of the face, in order to stretch the muscles of the upper back (photo 2). Exercise is repeated 5-10 times (Dionyssiots Y., 2010 c).



Fig. 13. *Stretching muscles of the lumbar spine:* The subject is kneeling on the floor with knees slightly apart (photo 1), raises the arms high towards the ceiling and carefully bends forwards, until the palms touch the floor (photo 2, 3), keeping this position for several seconds and repeats 5 times (Dionyssiotis Y., 2010c).

3.2.5 Exercises to improve functional ability – Osteoporosis and daily living activities

The program of exercises becomes more efficient if combined with the use of proper body mechanics and posture in everyday activities.



Fig. 14. *Lifting, carrying and placing weights; the correct and wrong way to lift and place objects:* The correct way for the osteoporotic patient to lift an object is to bend the knees, the hips and the ankles so that the object is at waist level. Bringing the object towards him with both hands and returning to the upright position using the strength of both feet. The spine should be straight during this movement, keeping the head and chest upright and the abdominal muscles tight. An osteoporotic patient is not allowed to lift more than 5-10 kg. The subject stands next to the object keeping the back straight bending the knees and lifting the weight using the strength of the feet and not that of the back, avoiding turning or rotating during the weight lift. The weight must be kept at the level of the waist. When transferring a heavy object, it is preferable to push rather than to pull it and while carrying a weight to separate it evenly on both sides of the body. The abdominal muscles should be flexed, so that the back is in the correct position (Dionyssiotis Y., 2010 c).

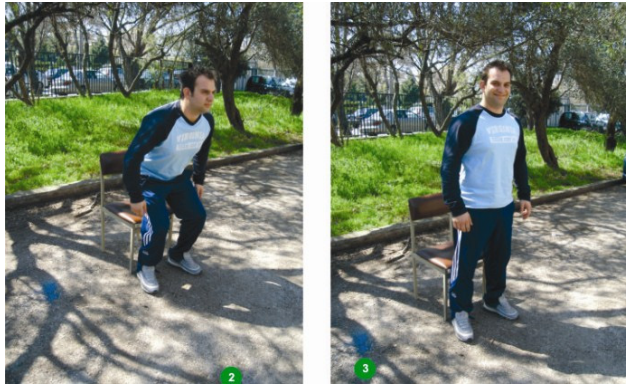


Fig. 15. *The correct way for the osteoporotic patient to get up from chair: The head and the chest must be in the upright position, the body must be bent forward using the hip joint and the base of the spine must be slightly bent with the help of abdominal muscle contraction. Standing up is achieved using the leg muscles. The subject should sit at the edge of the chair with feet slightly behind the knees, pushing forward by placing the weight on toes of the feet while getting up. If necessary the arm rests can be helpful in getting up from the chair. With this way subject is getting up keeping the back and the neck straight (Dionyssiotis Y., 2010 c).*

3.2.6 Whole body vibration as antiosteoporotic intervention

Vibration platforms are used in rehabilitation of osteoporosis, based on the concept that non-invasive, short-duration, mechanical stimulation could have an impact on osteoporosis risk. The mechanical loading of bone can be done with application of non-physiological factors, such as vibrations that combine dynamic loads and high intensity loading on the skeleton (Dionyssiotis, 2008b). The implementation should be shortly and has specific indications, contraindications and adverse reactions. These machines cause whole-body vibration. The vibration is a mechanical stimulation of the whole body; the person is standing on the vibration platform trying to keep his head and body straight and upright. All the muscles that keep the body in this position are forced to react to the oscillating movements provided by the device. The duration of this exercise depends on the type of machine in order to have measurable results and benefits.

According to the mechanostat theory bones need great forces for their development. The mechanical loading of bone can be done either with usual exercise activities as those reported in subchapter 3.2 or by applying non-physiological factors, such as body vibration. With platforms goal is achieved safely, without injury and quickly. Mechanical loads are applied in a dynamic way with a high intensity defined by its frequency (hertz) and magnitude, where magnitude is expressed as vertical acceleration (g ; $1g=9.8 \text{ m/s}^2$ acceleration due to gravity) or vertical displacement (millimeters). In the scientific world there is a debate about how exercise with vibrations develops bones. One theory holds that low vibration intensity but high frequency can cause osteogenic response by direct action on bone (Rubin et al., 2001). They support the following concept: because of small strains caused by this mechanism, there are benefits to bone without the risk of causing mechanical damage.

The credibility of this theory has been demonstrated in sheep, where one arm vibration caused a 34% increase in volumetric trabecular bone mineral density of the femur (Rubin et al., 2002). Moreover through this type of vibration trabecular bone density of the tibia in children with cerebral palsy was increased, whereas bone loss was expected without treatment (Ward et al., 2004). A recent study demonstrated benefits in postmenopausal women: an increase of 2.2% and 1.7% in bone density of the hip and spine respectively (Rubin et al., 2004). The second theory supports the concept of the important action of the muscles; vibrations make bones stronger through powerful muscular contractions (Rauch & Schoenau, 2001; Rittweger et al., 2000; Schiessl et al., 1998). In postmenopausal women, bone density increased by 1% after 6 months when vibration of static and dynamic knee-extensor exercises on a vibration platform (35-40 Hz, 2.28-5.09g) was performed which also increased muscle strength (Verschueren et al., 2004). However, these increases were also evident in the comparison group of women who performed traditional resistance exercises. A study performed on immobilized young men (Berlin bed rest study) concluded that a combination of vibration and resistance exercises prevent bone loss due to immobilization (Rittweger & Felsenberg, 2004). A systematic review and meta-analysis found significant but small improvements in BMD in postmenopausal women and children and adolescents, but not in young adults (Slatkowska et al., 2010).



Fig. 16. Galileo vibration platform (Novotec Medical GmbH, Pforzheim, Germany, with permission).

3.3 Exercise and bone density

The effect of aerobic exercise on bone density has been studied by review papers which report a decrease in bone loss at the spine and wrist but not at the hip (Bonaiuti et al., 2002; Martyn-St James & Carroll, 2008; Martyn-St James & Carroll, 2006). In meta-analysis studies which reviewed the effects of walking on bone density showed that walking has a small effect on sustaining bone density at the spine in postmenopausal women, however it has a significant positive effect on the femoral neck and concludes that other types of exercises which provide larger “targeted” weight bearing forces are needed to maintain bone density in this group (Martyn-St James & Carroll, 2006). In a review of 35 RCT’s it was shown that in premenopausal women and in postmenopausal women intense exercise probably had a

positive effect on the femoral neck and in spinal lumbar bone density, where less intensive exercise also helped (Kerr et al., 1996). In one meta-analysis study it was found that systematic high intensity resistance training is required for the maintenance of spinal lumbar bone density in postmenopausal women; however weight bearing exercise is necessary to help bone density of the hip beyond any other therapeutic intervention (Kelley, 1998).

In a three year period during the EFOPS study (Erlangen Fitness Osteoporosis Study), which included an exercise protocol with a combined strengthening program, jumping and high intensity resistance training in early onset postmenopausal women, sustained the bone density in the spine, the hip and in the heel, however not in the forearm. A well planned study which compared muscle strengthening exercises with weights and with resistance exercises with repetitions showed that the weight used was more important than the number of repetitions in postmenopausal bone (Engelke et al., 2006). A similar analysis in men revealed similar results (Kelley et al., 2000). With respect to bone quality a review study which used peripheral quantitative computed tomography (pQCT) revealed that exercise possibly increased bone mass and geometry in postmenopausal women, changes which theoretically increase bone resistance. Specifically, the effects of exercise are moderate, area specific and act primarily on cortical rather than trabecular bone (Hamilton et al., 2010).

3.4 Combined exercise with calcium, bisphosphonates

A decreased rate of bone loss in postmenopausal women undergoing exercise and taking calcium supplements is reported in comparison with exercisers only suggesting that calcium deficiency reduces the efficacy of loading to improve bone mass (Prince et al., 2006). In another study included 1890 pre- and postmenopausal women measured by quantitative ultrasound (QUS) at the heel and assessed with validated questionnaire according to physical activity and daily calcium consumption (greater than or less than 800 mg/day) was found that systematically active premenopausal and postmenopausal women had significantly higher values of QUS parameters than their sedentary and moderately active counterparts. Moreover a statistically significant difference in QUS T-score between sedentary premenopausal women and those who exercise systematically was found suggesting that vigorous physical activity is a regulator of bone status during premenopausal years (Dionyssiotis et al, 2010a).

In a randomized, double-blind, placebo-controlled trial the primary endpoint was the 12-month change in bone mass and geometry of the effects of weight-bearing jumping exercise conducted in an average 1.6 ± 0.9 (mean \pm SD) times a week and oral alendronate, alone or in combination, measured with dual-energy X-ray absorptiometry and peripheral computed tomography at several axial and limb sites. A total of 164 healthy, sedentary, early postmenopausal women were randomly assigned to one of four experimental groups: (1) 5 mg of alendronate daily plus progressive jumping exercise, (2) 5 mg alendronate, (3) placebo plus progressive jumping exercise, or (4) placebo. Alendronate daily was effective in increasing bone mass at the lumbar spine and femoral neck but did not affect other bone sites. Exercise alone had no effect on bone mass at the lumbar spine or femoral neck; it had neither an additive nor an interactive effect with alendronate at these bone sites. However, at the distal tibia the mean increase in the section modulus (a bone strength parameter) and in the ratio of cortical bone to total bone area were statistically significant in the exercise group compared to the non exercise group, indicating exercise-induced thickening of the bone cortex. The authors concluded that alendronate is effective in increasing bone mass at

the lumbar spine and femoral neck, while exercise is effective in increasing the mechanical properties of bone at some of the most loaded bone sites (Uusi-Rasi et al., 2003).

On the other hand the combined and separate effects of exercise training and bisphosphonate (etidronate) therapy on bone mineral in postmenopausal women were investigated in forty-eight postmenopausal women randomly assigned to groups that took intermittent cyclical etidronate; performed strength training (3 d/week) and received matched placebo; combined strength training with etidronate; or took placebo and served as non-exercising controls. Bone mineral was assessed by dual-energy X-ray absorptiometry before and after 12 months of intervention changes in bone mineral density (BMD) of the lumbar spine were greater in the subjects given etidronate compared with placebo, while exercise had no effect. No effect of etidronate or exercise on the proximal femur and there was no interaction between exercise and etidronate at any bone site was found (Chilibeck et al., 2002).

4. Modern orthoses in osteoporosis

Traditionally, spinal orthoses have been used in the management of thoracolumbar injuries treated with or without surgical stabilization. The vast majority of orthoses, however, are used in patients with low back pain (Perry, 1970). These orthoses, however, have never been tested under standardized conditions. Especially, no prospective, randomized, and controlled clinical trials are available to document efficacy according to the criteria of evidence-based medicine. Moreover, there is a lack of specific studies comparing various types of braces and orthoses. This is also the case for osteoporosis, in which approximately one-fourth of women above 50 years of age have one or more vertebral fractures (Melton, 1993).

Even though, it is widely accepted that spinal orthoses whether made of cloth, metal, or plastic, or whether rigid or flexible, relieve pain and promote the healing process by stabilizing the spine i.e. reducing the load applied on the anterior column and vertebral body by restraining any attempt of forward flexion. The most broadly used types of spinal orthoses use a three-point pressure system (Dionyssiottis et al., 2008; Mazanec et al., 2003): a) the TLSO type (Knight-Taylor, Jewett, CASH or Cruciform Anterior Sternal Hyperextension brace, Boston); that provides support to the thoracolumbosacral spine by making it adopt an anatomically correct position. The CASH or Jewett brace has been favoured for patients with acute vertebral fractures. The goal of these braces is to provide forces to encourage hyperextension. However, a drawback to these orthoses is the limited compliance because of their rigid configuration, b) the PTS (Posture Training Support) type, or the newer postural training support vest with weights (PTSW), two orthoses made of a softer material, gained popularity because of their improved comfort and increased compliance. The postural training support is worn over the shoulders similar to a mini-backpack and has a pocket into which small weights (total 1.75 lb) weights are added. The postural training support vest with weights is similar except that it is fashioned as a vest, with a Velcro attachment that fastens around the abdomen (Sinaki & Lynn, 2002), c) Spinomed and Spinomed active based on biofeedback theory (Pfeifer et al., 2004; Pfeifer et al., 2011); Spinomed consists of an abdominal pad, splint along the spine, back pad, and a system of belts with Velcro. The back orthosis consists of a back pad, which is workable as a cold material, and a system of belts with Velcro. This allows adjustments for individual sizes by an orthopedic technician. The orthosis weighs 450 g and is worn like a back pad and d) Osteomed, which is based upon

the gate control theory of pain (Vogt et al., 2008); the external appearance of the orthosis Osteomed resembles an item of clothing characterised by a constructively functional cut with Velcro tabs exerting pressure in the lumbosacral region as well as air chamber pads fixed in the paravertebral and lumbosacral areas which are filled with air to between 2/3 and 3/4 of their maximum capacity (Vogt et al., 2008).



Fig. 17. Front, back and lateral view of the Spinomed (unpublished images of Dionyssiotis et al.)



Fig. 18. Front, back and lateral view of the Spinomed active orthosis for men and women (Medi-Bayreuth, Bayreuth, Germany, with permission).

In a controlled pilot study with a 4-week observation period the strength of the back extensors was reduced to below the initial value in 40% of female patients wearing a stable orthotic device pointed out that orthotic devices impose a risk of reduction in muscular strength (Kaplan et al., 1996). On the contrary, recently published results of women with established osteoporosis and/or an angle of kyphosis more than 55 degrees wearing Spinomed for at least 2 hours/day for 6 months showing significantly decreased back pain ($p=0.001$) (evaluation was performed using visual analogue scale at the beginning and 6 months follow up of the examination) and increased personal isometric trunk muscle strength (figure 19) (Dionyssiotis et al., 2010b). Moreover in another Spinomed study subjects separated in two groups, the control and orthosis group, who switched after 6 months. Wearing the orthosis resulted in a 73% increase in back extensor strength, a 58% increase in abdominal flexor strength, most likely because of increased muscular activity while wearing the orthosis, a 11% decrease in angle of kyphosis, a 25% decrease in body sway, a 7% increase in vital capacity, a 38% decrease in average pain, a 15% increase in well-being, and a 27% decrease in limitations of daily living (Pfeifer et al., 2004).

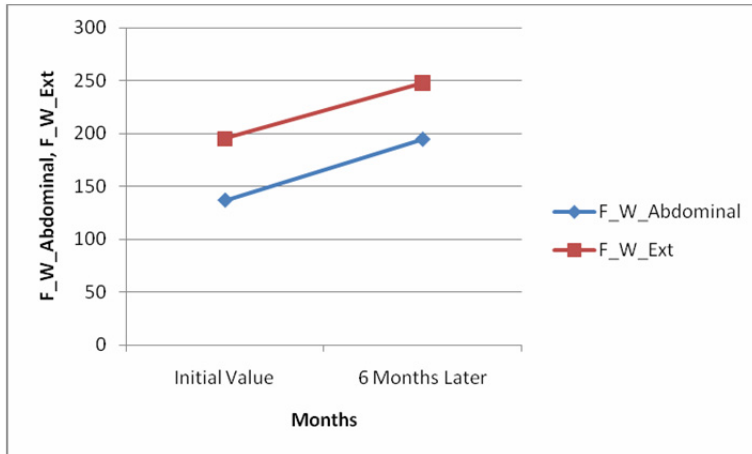


Fig. 19. Schematic presentation of differences in the values of personal isometric force: Force (F)/Weight (W) in abdominals and extensors muscles (F/W abdominals and F/W extensors, respectively, after 6 months wearing Spinomed orthosis (F: force in Newton, W: weight in Kg), measured with ISO-RACK device (Digimax, MechaTronic, Hamm, Germany). Figure adapted from Dionyssiotis et al., 2010b (with permission).

According to the results obtained from Osteomed studies, the orthosis brings an active erection of the spine of 60% on average of the deliberate maximum possible active erection. The wearing of the orthosis leads to an improvement of posture and statics (Vogt et al., 2005), a straightening of the spine of on average 46% of the conscious maximum achievable straightening (Vogt et al., 2008) and a statistically significant and clinically relevant reduction in chronic back pain by approximately 25% in female patients with osteoporosis worn it in a period of 2.5 months (Fink et al., 2007).

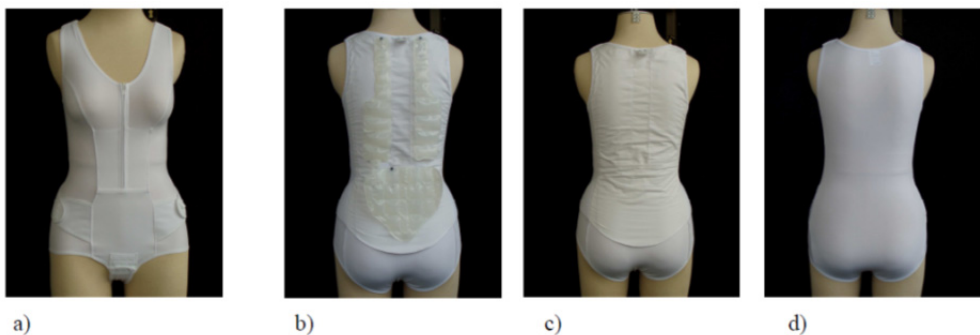


Fig. 20. a) Front view of the Osteomed osteoporosis orthosis (Osteomed, Thaemert Ltd, Germany), b) Dorsal view of the Osteomed osteoporosis orthosis (for demonstration purposes the air chamber pads are shown on the outside), c) View of the orthosis without air chamber pads, d) View of the placebo device (adapted from Fink et al., 2006, with permission).

Strengthening the back muscles not only maintains bone density in the spine but also reduces the risk of vertebral fractures. Ten years after a 2-year back exercise program in women fractures, both wedging and vertebral compression fractures, were significantly less (only 11% in the exercise group as compared to 30% in the control group) several years after the exercises were discontinued (Sinaki et al., 2002).

5. Prevention of falls and fall related fractures

An important issue in rehabilitation medicine is the prevention of falls and fall related fractures. Falls is a serious problem facing elderly persons. Falling results in increased mortality, morbidity, reduced functioning and premature nursing home admissions. Falls generally result from an interaction of multiple and diverse risk factors and situations, many of which can be corrected (Dionyssiatis et al., 2008a).

Falls can also result in deterioration of physical functioning and quality of life due to injury or due to fear of falling; 16% of fallers reported that they limited their usual activity because of fear of falling and one third of fallers reduced their participation in social activities (Nevitt et al., 1991). Fear of falling is reported by one in four older people in the community and can lead to distress and reduced quality of life, increased medication use and activity restriction, further decline in physical functioning, greater falling risk and admission to institutional care (Yardley et al., 2005). It is necessary to assess possible intrinsic and extrinsic risk factors for falls, as well as the exposure to individual's risk (Todd & Skelton, 2004).

Identifying risk factors is as important as appreciating the interaction and probable synergism between multiple risk factors because the percentage of persons falling increased from 27% for those with no or one risk factor to 78% for those with four or more risk factors (Tinetti et al., 1988). Important potentially modifiable risk factors for community-dwelling older adults are: mental status and psychotropic drugs, multiple drugs, environmental hazards, vision, lower extremity impairments, balance, gait status and for institution-dwelling older adults: mental status, depression, urinary incontinence, hypotension, hearing, balance, gait, lower extremity impairments, low activity level (exercise less than once a week), psychotropic drugs, cardiac drugs, analgesics and use of a mechanical restraint; non-modifiable risk factors (i.e. hemiplegia, blindness) also exist (Moreland et al., 2003).

Interventions to prevent falls may be planned to reduce a single internal or external risk factor of falling or be broadly focused to reduce multiple risk factors simultaneously (Sjösten et al., 2007). Single evidence based interventions include exercise, reassessment of medications and environmental modification (American Geriatrics Society [AGS], British Geriatrics Society [BGS], and American Academy of Orthopaedic Surgeons [AAOS], 2001; Tinetti, 2003). Although exercise has many proven benefits, the optimal type, duration and intensity of exercise for falls prevention remain unclear. Older people who have had recurrent falls should be offered long-term exercise and balance training (Dionyssiatis et al., 2008a).

5.1 Exercise for falls prevention

5.1.1 Balance exercises

Without good balance, there is always the danger of fracture. This type of exercise is the most important in falls prevention. Simple exercises for balance are walking heel to toe beside a wall or rail and balancing on one foot. The purpose of the exercises is the development of synchronized movements, resulting in balanced sitting and standing positions (Dionyssiatis, 2010c).



Fig. 21. Heel to toe exercise and balance standing on one foot: walking heel to toe beside a wall or rail for a short time. In alternative standing at the side of a chair (for safety) and leaning on the chair with one hand, whereas at the same time the opposite leg is raised with the knee bent as shown in the picture. Subjects perform the exercise, first with open and then with closed eyes and continue by changing side and leg of support. Ten repetitions for each leg are necessary (Dionyssiotsis Y., 2010 c).

5.1.2 Coordination exercises

These exercises help the cooperation of muscle and nerves in order to avoid falls and fractures and should be done routinely every day for at least 5 minutes. This category includes exercises such as marching, walking around a chair and throwing and catching a ball.

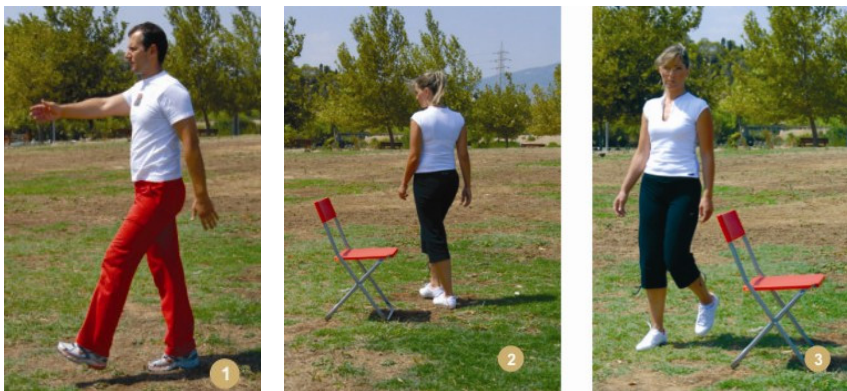


Fig. 22. Marching (photo 1) and walking around a chair (photos 2 and 3). Marching is an excellent exercise for coordination. Training consists of the simultaneous movement of one arm and the opposite leg in turn. During the execution of the exercise, the head must look forward; the arms must be slightly bent on the elbows and must reach up to the height of the shoulders. Placing a chair in a room, to make it able to walk around it on all sides, walking clockwise and then counter clockwise, as fast as they can, (should stop before getting dizzy) and repeat for 5 times (Dionyssiotsis Y., 2010 c).



Fig. 23. Exercise balls. Throwing and catching a ball is a very good exercise for coordination. The exercise is performed for security, from the sitting position and the ball thrown at a low height (photos 4 and 5). After enough practice at the previous exercise and while still in the sitting position, the ball can be thrown to and from another person sitting opposite (photos 6 and 7), (Dionyssiotis Y., 2010 c).

Type Balance & Coordination	Target	Intensity Frequency Duration	Time to target
Execution in parallel bars or next to a wall or a chair, because it has to be safe, in order to avoid falls	Improving coordinated movements resulting an improve in balance in seated and standing position	medium intensity 5-7 times/week 5-10 min	2-4 weeks

Table 3. Balance and coordination exercises are important for falls prevention; the table summarises the following characteristics of this type of exercise: how we can do them, which are the targets, the intensity, frequency and duration of the program and when to expect the results (Dionyssiotis Y., 2010 c).

5.1.3 Tai Chi

Tai Chi is a promising type of balance exercise, although it requires further evaluation before it can be recommended as the preferred method for balance training (AGS, BGS, AAOS, 2001). Tai Chi which consists of slow, rhythmic movements emphasizing on the trunk rotation, weight shifting, coordination, and a gradual narrowing of the lower extremities position is thought to be an excellent choice of exercise for the elderly. There is experimental evidence from both cross-sectional and longitudinal studies that Tai Chi exercise has beneficial effects on balance control and that the postural stability is improved

more by Tai Chi than by other types of exercise (Graafmans et al., 1996). Although Tai Chi is probably the exercise programme we would least recommend to people who have previously suffered fractures because they show a level of frailty that means they could not fully participate in Tai Chi unless it was adapted so much it was no longer dynamic balance training (Skelton D, personal communication). From the most training studies after hip fracture it seems that combined training with task-specific and functionally based exercises may be a sensible way of retraining leg strength, balance and gait ability in elderly people after a hip fracture. The training thus may include a variety of gait exercises, step exercises, stair climbing, and rising from and sitting down on a chair (Sherrington et al., 2004; Hauer et al., 2002; Lindelöf et al., 2002).

5.1.4 Clinical trials and multifactorial intervention

A review about the effectiveness of interventions to prevent falls in older adults concluded that exercise programs help prevent falls with no differences between types of exercise (Chang et al., 2004). The results from the FICSIT trials (Frailty and Injuries: Cooperative Studies of Intervention Techniques) suggest that interventions that addressed strength alone did not reduce falls. On the other side balance training may be more effective in lowering falls risk than the other exercise components (Lord et al., 2007).

Others concluded that exercise programmes must be regular and sustainable to be effective but more trials are required to determine the exercise type, frequency, duration, and intensity that are most effective in lowering falls risk in different groups of older people (Gardner et al., 2000). However, as ageing is related with reduced physical functioning, exercise prescription for falls prevention, beyond balance and strength training, may include exercises to increase the functional capabilities in all elderly. The suggested guidelines especially for the Greek population are low intensity balance exercises (tandem walking and standing on one's foot) combined with coordination exercises. Individuals who are frail, severely kyphotic or suffer from pain or poor balance may benefit from water exercise (hydrotherapy). People are also advised to undergo strengthening exercises of the quadriceps, hip abductors/extensors, back extensors and the arm muscles (Dionysiotis et al., 2008a)

Frequent fallers should have their medications reviewed. Studies have indicated that the use of medication is a potential cause for falls (Hartikainen et al., 2007). Central nervous system drugs, especially psychotropics warrant particular attention, since there is very strong evidence that use of these medications is linked to the occurrence of falls. Reducing the total number of medications to four or fewer, if feasible, has also been demonstrated to reduce the risk of falling (AGS, BGS, AAOS, 2001; Tinetti, 2003). Environmental hazards could be a cause of falls (Lord et al., 2007). In reducing environmental hazards, falls prevention programs may need to provide and install safety devices particularly in the homes (Wyman et al., 2007). Studies have shown that when older patients at increased risk of falls are discharged from the hospital, a facilitated environmental home assessment should be considered (AGS, BGS, AAOS, 2001; Tinetti, 2003).

There is emerging clinical evidence that alfacalcidol, a prodrug of D-hormone, improves muscle function (Runge & Schacht, 2005). In community dwelling elderly women and men with a total calcium intake of more than 500 mg daily and normal vitamin D serum levels 1 µg alfacalcidol daily reduced significantly the number of falls (-54%) and fallers (-55%) (Dukas et al., 2004). Other authors reported that cholecalciferol-calcium supplementation

reduces falls by 46% to 65% in community-dwelling older women, but has a neutral effect on falls in men (Bischoff-Ferrari et al., 2006). Prevention may be even more effective when multiple risk factors of falls are taken into account. Most multifactorial fall prevention programmes have been successful in reducing the incidence of falls and risk factors of falling, especially when prevention has been individually tailored and targeted to populations at high risk of falling (Moreland et al., 2003).

Multifactorial interventions should include: a) among community-dwelling older persons (i.e. those living in their own homes), gait training and advice on the appropriate use of assistive devices, review and modification of medication, especially psychotropic medication, exercise programs, with balance training as one of the components, treatment of postural hypotension, modification of environmental hazards and treatment of cardiovascular disorders, b) among older persons in long-term care and assisted living settings staff education programs, gait training and advice on the appropriate use of assistive devices and review and modification of medications, especially psychotropic medications (AGS, BGS, AAOS, 2001; Tinetti, 2003).

6. Rehabilitation of common osteoporotic fractures

Successful operative treatment of hip fracture victims is necessary for the optimization of post-injury mobility and the functional recovery of the patient (Koval, 2005). Two evidence-based clinical practice guidelines suggesting possible treatments and rehabilitation pathways for hip fracture patients, agree that it would be best if they underwent multidisciplinary rehabilitation (Scottish Intercollegiate Guidelines Network [SIGN], 2002; Chilov et al., 2003). Multidisciplinary rehabilitation can be defined as the combined and coordinated use of medical, social, educational and vocational measures for training or retraining the individual to the highest possible level of function (Cameron, 2005).

Hip fracture patients should start breathing exercises so that pulmonary secretions are drained, thus reducing the risk of atelectasias and other complications deriving from the pulmonary system. "Pump like" energetic exercises (ankle pumps) and dorsal/plantar flexion of the foot, knee joint flexion, exercises for the hip and thigh, abduction exercises for the gluteal muscles and exercises for the quadriceps are important. Exercises of the upper extremities and trunk must also be part of the rehabilitation program, so that the patient can move in bed, stand up from a chair and later on be able to mobilize himself by using crutches or a stick. Abdominal and dorsal muscles should also be exercised isometrically and then energetically, in order to minimize the risk of low back pain during weight-bearing exercises (a detailed rehabilitation program is published in Dionyssiotis et al., 2008a).

After a vertebral fracture a program of physical therapy is necessary and helps prevent deformity by strengthening anti-gravity muscles and promoting postural retraining. Breathing exercises promote thoracic expansion and improve the heavily degraded pulmonary function found in patients with spinal osteoporotic fractures (Pfeifer et al., 2004). Instruction on the proper way of lifting things, as well as how to appropriately use a walker or a cane, could be beneficial and thus is strongly recommended. Patients with fractures could perform low-intensity exercise and gentle strengthening programs (e.g., Tai Chi and hydrotherapy) and are strongly recommended to avoid high impact exercise or movements, so that they avoid suffering new vertebral fractures (Tosi et al., 2004). Forward bending of the spine or flexion exercises, especially in combination with twisting, should be avoided.

This includes several old favourite exercises which are now considered outdated, namely straight-leg toe touches and sit ups (or crunches) for strengthening the abdominal muscles (Bassey, 2001). The latter are associated with a dramatically increased rate of vertebral fracture in osteoporotic women (89% compared to 16% of those who did extension exercises) (Sinaki & Mikkelsen, 1984). As the acute fracture pain subsides, a walking program can begin with gentle strengthening exercises focusing on spinal extensor muscles (Bonner et al., 2003). A carefully supervised rehabilitation program should be started after 3 to 4 months, to strengthen the spinal extensor and abdominal muscles more aggressively (a detailed rehabilitation program is published in Dionyssiotis et al., 2008a).

Physical therapy after a Colles' fracture consists of muscle strengthening, motion range recovery, wound healing and scar adhesion. Early reduction of oedema is of primary importance in determining hand functions. Elevation of the hand above the heart's level and an active range of motion exercises are instructed to facilitate the pumping action of hand muscles to decrease swelling. Physical modalities and exercise programs consisting of passive and active range of motion; transverse scar massages, progressive resistive exercise, focusing on strengthening both extrinsic and intrinsic muscle groups of the hand are necessary (Morey & Watson, 1986; Dionyssiotis et al., 2008a). Physical therapy is followed by occupational therapy for 3 weeks (Christensen et al., 2001).

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