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Modern Rehabilitation in Osteoporosis, Falls, and Fractures

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ABSTRACT: In prevention and management of osteoporosis, modern rehabilitation should focus on how to increase muscular and bone strength. Resistance exercises are beneficial for muscle and bone strength, and weight-bearing exercises help maintain fitness and bone mass. In subjects at higher risk for osteoporotic fractures, particular attention should be paid to improving balance – the most important element in falls prevention. Given the close interaction between osteoporosis and falls, prevention of fractures should be based on factors related to bone strength and risk factors for falls. Fractures are the most serious complication of osteoporosis and may be prevented. The use of modern spinal orthosis helps to reduce pain and improve posture. Vibration platforms are used in rehabilitation of osteoporosis, based on the concept that noninvasive, short-duration, mechanical stimulation could have an impact on osteoporosis risk. Pharmacologic therapy should be added for those at high risk of fracture, and vitamin D/calcium supplementation is essential in all prevention strategies. Success of rehabilitation in osteoporotic and fractured subjects through an individualized educational approach optimizes function to the highest level of independence while improving the overall quality of life.

KEYWORDS: osteoporosis, rehabilitation, exercise, orthosis, falls, calcium, vitamin D, vibration platforms

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Introduction

Osteoporosis is a metabolic bone disease usually occurring with increasing age that predominantly affects postmenopausal women and older people. However, in individual cases, it could occur in younger people, ie, 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 change depending on the stage of disease. In prevention and management of osteoporosis, modern rehabilitation should not only focus on bone strength while 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. Pharmacologic treatment increases bone strength but has no effect on muscle strengthening or balance in general, because there is evidence that vitamin D improves muscle function and decreases the incidence of falls. Moreover, beyond drugs, there are other interventions often overlooked: supplementation with calcium, exercise programs, orthoses, vitamin D, and the prevention of falls.[1]

Falls are one of the most frequent and serious problems that elderly people face; their association with mortality, morbidity, reduced functionality, and premature nursing home admissions has been proven; they are usually the result of interaction of multiple and diverse risk factors and situations that may be corrected many times; their interaction is modified by age, disease, and the presence of hazards in the environment.[2]

A key point regarding falls is that the increased incidence of falls is combined with increased susceptibility to injury. This propensity of the elderly to injuries results from the high incidence of accompanying diseases, such as osteoporosis, where the prevention and management should not only focus on bone strengthening but mainly shifted to increasing muscle strength and power and improving balance as they protect against falls and related fractures.[1,2]

We performed a systematic literature search. A search was conducted in PubMed, PubMed Central, and Cochrane. Keywords used to perform the search were "osteoporosis," "rehabilitation," "exercise," "orthosis," "falls," "calcium," "vitamin D," and "vibration platforms." Limits that were used included English and German languages, clinical trial, and randomized controlled trials; review articles and meta-analyses were identified. The investigated articles needed to include a rehabilitation part related to osteoporosis and/or fractures. A rehabilitation physician (Y.D.) reviewed the articles to determine whether they met the inclusion criteria. For the inclusion process, the full article was obtained and read. Publications that met the inclusion criteria were reviewed, and data such as the study population, design characteristics, and primary results relevant to bone loss and fractures were recorded. In addition, the references cited in the article that met the inclusion criteria were reviewed to identify additional trials that may not have been identified from the initial literature searches. Disagreement about inclusion of articles was resolved by discussion and consensus between Y.D. and the other authors.

Calcium, Vitamin D, and Vitamin D Analogs

All the studies on the effectiveness of anti-osteoporotic drugs required the intake 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.[3,4] Trials reporting bone mineral density (BMD), 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 BMD was evident in most studies.[5] In opposition to the findings on the use of combination of calcium and vitamin D, studies that researched the relative role of calcium or vitamin D separately produced conflicting results. Moreover, calcium and vitamin D or vitamin D by itself increases muscular strength and decreases the number of falls.[6]

A large amount of data suggests that vitamin D regulates skeletal muscle physiology. On this point, this theory mostly originated from clinical observations of improvements in skeletal muscle strength or function in populations where a metabolic bone disorder was accompanied by decreased serum 25(OH)D concentrations. Today, results from cell and experimental animal studies explain the muscular weakness in patients with low-serum 25(OH)D concentrations, although in humans, results are limited to the association between vitamin D and strength.[7,8]

When serum 25(OH)D concentrations were increased, muscle function was improved. This information is based on the presence of the vitamin D receptor in muscle fibers and developmental and functional deficits in vitamin D receptor knockout mice. Moreover, genetic background (genes) is responsible for regulation of protein synthesis through 1,25-dihydroxyvitamin D (1,25(OH)2D) in muscles.[9,10]

Treatment with 8,400 IU vitamin D3 once weekly raised 25(OH)D concentrations in vitamin D–insufficient elderly subjects, but did not improve neuromuscular parameters. On the contrary, in Longitudinal Aging Study Amsterdam (LASA), an epidemiologic study included subjects with severe vitamin D deficiency, higher serum 25(OH)D concentrations were related to better physical performance, and vitamin D status was related with the decline in physical performance during aging.[11,12]

Cholecalciferol–calcium supplementation reduces falls by 46% to 65% in community-dwelling older women, but has a neutral effect on falls in men.[13] Vitamin D supplementation was associated with an incident rate ratio for falling of 0.73, odds ratio for ever falling of 0.82, while subjects who reported half compliance demonstrated values of 0.63 and 0.70, respectively.[14] Broe et al found that subjects in the highest dose group had a 72% lower adjusted-incidence rate ratio of falls than participants receiving placebo.[15] Other authors reported that there is emerging clinical evidence that alfacalcidol improves muscle function.[6,16] However, there is no evidence that improving muscle strength or reducing falls is proven for fracture reduction.

Exercise

Mechanostat theory–Targeted exercise for bone loss prevention. 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 damage on bone structure; on the other hand, stress strain that exceeds a certain threshold leads to generation and thereby adjusts the strength of the bone load usually applied.[17] This is a feedback cycle, which is usually called the mechanostat.[18]

The mechanostat theory describes a system in which a minimum effective strain (MES) is essential for maintaining bone.[19] If mechanical strains remain within a normal physiologic window (800–1,500 μstrain) bone structure is maintained (remodeling). Unloading (disuse) reduces mechanical strains leading to increased remodeling in favour of bone resorption. In the overload zone (1,500–3,000 μstrain), new bone is added in response to mechanical requirement (modeling) leading to increased bone strength. In the pathological overload zone (>15,000 μstrain), bone is fractured. A sufficient number of studies suggest the ability of oestrogen to alter the set point of bone strain. This is in response to mechanical loading as the result of an indirect effect of oestrogen receptors number.[20,21] The decrease in sensitivity of oestrogen receptors as a result of oestrogen deficiency may reduce the response of bone to mechanical loading. Strain of about 1,000 μstrain 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.[22]

Physical activity targeting muscles is the cornerstone of each rehabilitation program for prevention of bone loss. In postmenopausal individuals, results of physical activity studies on the positive association of physical activity with bone status are conflicting.[23,24] However, it is clear that physical activity is vital in adults, because it reduces the rate of bone loss during the perimenopausal period and decelerates bone loss associated with aging.[25,26] In the design of an exercise program to increase bone mass, we need to keep in mind the elements of specificity, overload, reversibility, initial values, and diminishing returns described by Drinkwater.[27] For example, a progressive jogging program charges and stimulates adaptation of the cardiovascular system, but does not stimulate an adaptive bone response that would increase bone density. There is definitely a threshold load which must be reached, and loading should be done in a way that mimics the physical loads.[28]

The osteogenic effects of exercise should be specific to the anatomical sites where the mechanical strain occurs.[29] The most common types of physical activities (ie, 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. The duration of the physical activity is also important; up to 2 hours/week is considered to positively affect bone mass maintenance.[30]

Muscle strengthening (programs focused on specific regions of the skeleton where fractures are most commonly expected, namely the spine, the hip, and the wrist), weight-bearing exercises with an impact on the bone higher than that during normal everyday activities, 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 prevention and management. Another principle is 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 type of bone and muscle stimulation, we challenge them in a new way, shifting the loading stress causing new results.[31]

The effect of aerobic exercise on bone density has been studied by review papers that report a decrease in bone loss at the spine and wrist but not at the hip.[32–34] Meta-analysis studies that 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. These studies conclude that other types of exercises that provide larger "targeted" weight-bearing forces are needed to maintain bone density in this group.[34] 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.[35]

However, the studies mentioned above provided BMD (g/cm^2) measured by radiographic techniques (single-photon absorptiometry (SPA), dual-photon absorptiometry (DPA), or dual X-ray absorptiometry (DXA)), which measure areal BMD. On the contrary, recently published studies with peripheral quantitative computed tomography (pQCT) evaluated volumetric BMD, bone mineral content, geometric properties, and the strength indexes of the tibia of jumping athletes of both sexes. They found higher values of periosteal, cortical area, and polar moment of inertia versus controls, suggesting a geometric adaptation-related improvement instead of BMD in response to long-term high-impact exercise.[36] Liu-Ambrose et al highlighted an increase in cortical volumetric BMD at the radius after 6 months of twice per week resistance training in women aged 75–85 years.[37] Specific characteristics of physical activity (ie, duration, frequency, and load) were all modestly and independently associated with bone geometry and strength, with duration of physical activity being the strongest predictor of bone parameters.[38] Adami et al using pQCT found at the radius in postmenopausal women after a 6-month upper limb loading program increased cortical bone area and BMC, but decreased trabecular BMC. The authors explained the findings via periosteal expansion and redistribution of bone minerals from the trabecular to cortical component.[39] With respect to bone quality, a review study which used pQCT revealed that exercise possibly increased bone mass and geometry in postmenopausal women, changes that theoretically increase bone resistance. Specifically, the effects of exercise are moderate, area specific, and act primarily on cortical rather than trabecular bone.[40] Recently published meta-analysis from six randomized controlled pQCT trials in postmenopausal women reported small but significant increases in volumetric trabecular and cortical BMD mostly after a year of an exercise program in early postmenopausal women.[41]

Whole body vibration. 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. 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.[31] Mechanical loads are applied in a dynamic way with a high intensity defined by its frequency (Hz) and magnitude, where magnitude is expressed as vertical acceleration (g; $1g = 9.8$ m/s^2 acceleration due to gravity) or vertical displacement (mm).[42]

Vibration training improves maximal strength (and other neuromuscular parameters) if the implementation is short

Figure 1. Galileo vibration platform (Novotec Medical GmbH, Pforzheim, Germany, with permission).[1]

and properly designed. Some recommendations are proposed: high transmission vibrations to the head are not allowed, frequencies should be higher than 20 Hz, and amplitudes should be low (1–2 mm) when vibration training is used for leisure sport and in the beginning of training in professional athletes. The duration for each session should be very short (20–60 seconds).[43] The International Society of Musculoskeletal and Neuronal Interactions (ISMNI) published expert recommendations for a common language and consistent use of well-defined terminology according to whole body vibration, because studies have raised many questions that can be answered only by careful scientific studies with understandable reports.[44,45]

Evidence from previous studies suggests that the more osteoporotic individuals may potentially increase BMD values more from whole body vibration.[46] 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.[47]

Exercise and osteoporotic fractures. In the National Health and Nutrition Examination Survey I (NHANES I), women who reported much recreational exercise had a 47% lower risk for hip fracture when compared to women who reported little recreational exercise.[48] The Nurses Health Study (NHS), a prospective 12-year study among postmenopausal women, found a 55% lower risk of hip fracture in active women with at least 24 METs-hours/week (MET is defined as the ratio of metabolic rate during a specific physical activity to a reference rate of metabolic rate at rest) compared with sedentary women with less than 3 METs-hours/week.[49] In the Study of Osteoporotic Fractures (SOF), a prospective cohort study included 9,704 Caucasian postmenopausal women aged 65 years and older, women who systematically walked for exercise had a significant 30% decrease in risk of hip fracture in comparison with women who did not walk regularly after a 4.1 years and 40% after a 7.6 years follow-up, respectively.[50,51] Moderate exercise was also associated with a 30% decrease in the risk of hip fractures when women were compared with those who do not exercise, as reported by the Leisure World Study, which included 8,600 middle-aged and elderly women; this is in line with similar results of a study of 5,049 elderly men.[52] The relation of occupational and recreational physical activity to fractures was investigated in the Tromso study. The relative risk of a low-energetic fracture in the weight-bearing skeleton (ie, hip) among the most physically active middle aged was 0.3 (CI: 0.1–0.7) among men and 0.9 (CI: 0.4–1.8) among women in comparison with the sedentary.[53] A meta-analysis of 13 prospective cohort studies with hip fracture as an end point shows that moderate-to-intensive physical activity is associated with a decrease in the risk of hip fracture by 45% (CI: 31–56) and 38% (CI: 31–44), respectively, in men and women.[54]

The European Vertebral Osteoporosis Study (EVOS) including 884 women with vertebral deformity and 6,646 controls (aged 50–79) found current walking or cycling more than 30 minutes per day to exert a 20% reduced risk of vertebral deformity in women in comparison to inactive women, while a relatively flat relationship of vertebral deformity to age was found in men.[55] In SOF in moderately to vigorously active women, the risk for vertebral fractures was significantly decreased by 33% compared to inactive women. No association was found between total physical activity, hours of household chores per day, and hours of sitting per day with wrist or vertebral fractures.[56] The results from the Tromso study showed less low-energetic fractures in the

Table 1. These recommendations are part of the Greek guidelines for osteoporosis and Falls prevention published from Hellenic Osteoporosis Foundation (A, B, C: grade of recommendation).[66]

RECOMMENDATIONS
• The effect of exercise on BMD is area specific. For this reason exercise should be targeted to points of clinical interest (A).
• Aerobic exercise is effective in reducing bone loss in the spine and wrist (A).
• Strength training exercises are effective in reducing bone loss and increasing muscle strength (A).
• Although exercise has proven benefits, the ideal type of exercise, duration and intensity in a Falls prevention program is not yet fully clear (B).
• Exercises that improve balance, including Tai Chi, are effective in populations with a high risk of falling (A).
• In patients who have fallen medications should to be reviewed and modified or discontinued as appropriate in light of the risk of future falls. Particular attention should be given to older people who take four or more medications and those taking psychotropic medications (C).
• The vitamin D supplementation reduces Falls (B).
• Necessary is the evaluation of the house in elderly patients with an increased risk of falling that receive discharge from the hospital in order to facilitate them under new conditions (B).
• There is no direct evidence that the use of assistive devices or educational programs alone helps prevent Falls . Therefore, although it can be effective elements of a multifactorial intervention program, the isolated use without attention to other risk factors cannot be recommended (C).

weight-bearing skeleton in active men aged 45 years or older, and more low-energetic fractures in the non-weight-bearing skeleton areas including the wrist, the proximal forearm, the hand, and the fingers, in women aged 45 years or older; among women aged 55 years or older, the most active women had lower risk of fractures in the weight-bearing skeleton.[53] In the Dubbo Osteoporosis Epidemiology Study (DOES), higher physical activity was protective against risk of atraumatic fractures in elderly men, expressed as a 14% reduction for 1 standard deviation change in physical activity; however, the magnitude of effect varied between fracture sites.[57] Finally, the relative risk for compression fracture in postmenopausal women was 2.7 times greater in controls than in a back exercise group 8 years after they had completed a 2-year, randomized, controlled trial of progressive, resistive back-strengthening exercises.[58]

Exercise in Combination with Calcium and Bisphosphonates

There are no valid data about falls prevention, if exercise is combined with calcium and 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.[59] In another study that included 1,890 pre- and postmenopausal women, it 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.[60]

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 of 1.6 ± 0.9 (mean ± SD) times a week and oral alendronate, alone or in combination, measured with DXA and peripheral computed tomography at several axial and limb sites. 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.[61]

On the other hand, no effect of etidronate or exercise on the proximal femur and no interaction between exercise and etidronate at any bone site were found.[62]

Interventions to Prevent Falls

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.[63,64]

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.[65] However, Tai Chi is probably the exercise program 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 that it was no longer dynamic balance training (Skelton D, personal communication). Low-intensity balance exercises (walking heal to toe and standing on one foot) along with coordination exercises are proposed for falls prevention. People with reduced bone strength can benefit from hydrotherapy in therapeutic pools or swimming in the sea. It is suggested to these people to perform strengthening exercises of the quadriceps, abductors, adductors, and shoulder muscles.[65]

According to the Greek guidelines of Hellenic Institution of osteoporosis, 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.[31,66]

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 hand, balance training may be more effective in lowering the risk of falls than the other exercise components.[67] However, as ageing is related with reduced physical functioning (frailty), exercise prescription for falls prevention, except balance and strength training, may include exercises to increase the functional capabilities in all elderly.[65,67]

Exercise and Risk of Falls

The individual risk factors for fall in the elderly are summarized as follows. Intrinsic risk factors that include a history of falls, age, gender, solitary lifestyle, race, drugs, medical conditions, impaired mobility and gait, deconditioning (immobility), psychological condition (fear of falling), nutritional deficiencies, cognitive disorders, attenuated vision, foot problems. Extrinsic risk factors are poor lighting, slippery floors, uneven surfaces, etc, and those that would lead any healthy elderly person to fall. Exposure to risk means the more passive and more active people are at greater risk of falls.[68]

Results from Osteoporotic Fractures in Men Study (MrOS), observed a relation of increased risk of falling with higher levels of self-reported physical activity; moreover, men with low leg power had consistent fall risk across levels of physical activity, while men with high leg power had increasing fall risk with increasing physical activity levels.[69]

A meta-analysis of the several separate studies composing the FICSIT study found a 17% reduction of falls in individuals participating in endurance training, balance training, and Tai Chi, while Tai Chi showed a 47% reduction in multiple falls during a four-month period compared to the controls.[70,71] A Cochrane review concluded that multiple-component group exercise reduced risk of falling by

17%, as did Tai Chi and individually prescribed multiple-component home-based exercise (35% and 23%, respectively). But the current evidence does not support the last intervention in people with severe visual impairment or mobility problems after a stroke, Parkinson's disease, or a hip fracture.[72–74]

Prevention of falls may be even more effective when taking into account multiple risk factors for falling. Most multifactorial falls prevention programs have been successful in reducing the incidence of falls and risk factors of falls, particularly when prevention is individually tailored for their needs and targeted at populations of high risk for falls. These results suggest that an individualized prevention program aimed at reducing multiple risk factors simultaneously in high-risk populations could be an effective strategy for preventing falls; however, the exact content of the most effective approaches remains unclear.[75]

Falls generally result from an interaction of multiple and diverse risk factors and situations, many of which can be corrected.[76] It is necessary to assess possible intrinsic and extrinsic risk factors for falls, as well as the individual's exposure to risk.[68,76] 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.[77]

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, and gait status. For institution-dwelling older adults, the risk factors are 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 (ie, hemiplegia, blindness) also exist.[78] Environmental hazards could be a cause of falls.[79] In reducing environmental hazards, fall prevention programs may need to provide and install safety devices particularly in the home.[80] 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.[63] Studies of multifactorial interventions, which included both devices (including alarms in bed, canes, walkers, and hip protection) and educational programs, have a demonstrated benefit. However, there is no direct evidence that only the use of aiding devices or educational programs can help the prevention of falls. Therefore, although they may be effective elements of a multifactorial intervention program, their isolated use without attention to other risk factors cannot be established.[31,81]

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.[75] Single evidence-based interventions include exercise, reassessment of medications, and environmental modification.[81]

Rehabilitation after Common Osteoporotic Fractures

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.[82,83]

A detailed rehabilitation program for hip, vertebral, and wrist fractures can be found here.[65] Spinal orthoses have been used in the management of thoracolumbar injuries treated with or without surgical stabilization. However, these orthoses have never been tested under standardized conditions. In particular, no prospective, randomized, and controlled clinical trials are available to document efficacy according to the criteria of evidence-based medicine. The PTS (Posture Training Support) type or the newer postural training support vest with weights (PTSW),[84] Spinomed and Spinomed active based on biofeedback theory,[85,86] and Osteomed based on gate control theory of pain.[87,88]

Recently published results of women with established osteoporosis wearing Spinomed for at least 2 hours/day for 6 months showed significantly decreased back pain and increased personal isometric trunk muscle strength.[89] Moreover, in another Spinomed study, subjects were separated into 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 27% decrease in limitations of daily living.[85] 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. This orthosis leads to an improvement of posture and statics, a straightening of the spine on average of 46% of the conscious maximum achievable straightening, and a statistically significant and clinically relevant reduction in chronic back pain by approximately 25% in female patients with osteoporosis who wore it during a period of 2.5 months.[90,91]

The effectiveness of the provision of hip protectors in reducing the incidence of hip fracture in older people is still not clearly established, although they may reduce the rate of hip fractures if made available to frail, older people in nursing care. It remains unknown from studies identified to date if these findings apply to all types of hip protectors. Some cluster-randomized trials have been associated with high risk of bias. Poor acceptance and adherence by older people who were offered hip protectors have been key factors contributing to the continuing uncertainty.[92]

Author Contributions

Conceived and designed the experiments: YD. Wrote the first draft of the manuscript: YD. Contributed to the writing of the manuscript: GS, PJP. Made critical revisions and approved final version: PJP. All authors reviewed and approved of the final manuscript.

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