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Osteoporosis and physical activity

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Brief summary

Physical activity is beneficial for bone mass, muscle strength, balance performance and pain relief in persons suffering from osteoporosis. Back extension exercises in specific are recommended to osteoporotic persons. Prevention of fragility fractures should focus both on the prevention of osteoporosis and the prevention of falls. Osteoporotic patients need adequate and skilled supervision for their individual rehabilitation and training. Physiotherapists should play a major role in motivating, encouraging, and advising osteoporotic persons to begin exercising and to become physically active for all their life.

Epidemiology and costs

In the year 2000 there were an estimated 9 million osteoporotic fractures of which 1.6 million were at the hip, 1.7 million at the forearm, and 1.4 million were clinical vertebral fractures. Seventy percent of hip fractures occurred in women. The greatest number of osteoporotic fractures occurred in Europe (34.8%) (Johnell et al. 2006). Scandinavian women have the highest incidence of hip fractures in the world (Johnell et al. 1992). The mean fracture-related costs estimated in euros (€) the year after a fracture were at €14 221 for hip, €12 544 for vertebral, and €2 147 for wrist fractures in Swedish patients. As regards to reduction in quality of life due to these fractures the yearly burden of osteoporosis in Sweden was estimated to €0.5 billion (Borgström et al. 2006).

Forearm fractures are very common in middle-aged women. Low forearm bone mineral density (BMD) is a risk factor for sustaining a forearm fracture. Forearm fracture in both genders might be a predictor of a later vertebral and/or hip fracture (Bengnér et al. 1985, Peel et al. 1994). The incidence of forearm fractures increases more in wintertime than for hip and vertebral fractures. A great proportion of falls occurs outdoors for distal forearm fractures, while hip fractures more often occur indoors (Arden et al. 1998, Nevitt et al. 2003). The incidences of humerus and hip fractures increase steeply with increasing age (Bengnér et al. 1988). The increased incidence results from a combination of decreasing BMD and an increased propensity of falling in higher ages (Kristinsdottir et al. 2000, Low Choy et al. 2007). Most hip fractures occur in the very elderly at an average age of 80 years (Löfman et al. 2002, Nilsson et al. 1991, Obrant 1996).

Health-related quality of life in persons with osteoporotic fractures

Osteoporotic hip and vertebral fractures are associated with considerable morbidity and mortality. Osteoporotic persons may have severe pain caused by vertebral fractures, though it has been estimated that at least half of all vertebral fractures are asymptomatic (Eastell 1998). Thus, there is only a moderate correlation between pain and the number of vertebral fractures, whereas disability often correlates better with the number of fractures (Lips 1998, Ross et al. 1994). A recent study in the U.S. showed that vertebral and hip fractures had a more prolonged impact on health-related quality of life (HRQL) two years after fracture, estimated by the SF-36 questionnaire, than forearm and humerus fractures (Hallberg et al. 2004). The disease-specific questionnaire called QUALEFFO-41 (the quality of life questionnaire of the

European foundation for osteoporosis) was developed specifically for patients with established vertebral osteoporosis. An association between a deteriorating HRQL measured by QUALEFFO-41 and an increasing number of vertebral fractures was confirmed (Lips et al. 1999, Lips et al. 2005).

Definition of osteoporosis and FRAX®

The World Health Organization (WHO) established diagnostic categories for osteoporosis in 1994 based on BMD values in healthy young adult women, which is referred to as the T-score. Osteopenia is a BMD value that lies between 1 and 2.5 SD below the young adult mean value, osteoporosis is a BMD value more than 2.5 SD below the young adult mean value, and established (or severe) osteoporosis is a BMD value more than 2.5 SD below the young adult mean value in the presence of one or more fragility fractures. The WHO definition is quantitative and based on measurements techniques using DXA (dual energy X-ray absorptiometry) at measurement sites such as the lumbar spine and the hip (WHO 1994).

The FRAX® tool has been developed by the WHO to evaluate fracture risk of patients. The FRAX® algorithms give the 10-year probability of a hip fracture and major osteoporotic fracture (clinical spine, forearm, hip or shoulder fracture) (Kanis et al. 2008).

Prevention of osteoporosis and fractures by physical activity

A primary factor associated with risk for osteoporosis is the maximal BMD of the skeleton (peak bone mass) developed during childhood and early adult years. The age of bone mineralization onset and the age of attainment of peak bone mass vary, according to gender and the bone region being studied. Peak bone mass usually occurs before the third decade *(*American College of Sports Medicine 2004, Lu et al. 1994). Peak bone mass is dependent primarily on genetic factors (70-80%), but it is also considerably influenced by physical activity and dietary calcium intake during adolescence (Mundy 1998). The age-related decrease of bone mass (regardless of gonadal hormone levels) generally is starting some time after the age of 50. The age-related bone loss is about 0.5% per year during the sixth and seventh decades, but accelerates substantially with advancing ages (Heaney 1998). In women there is an increased acceleration of bone loss at menopause (American College of Sports Med 2004, Mundy 1998).

There is a strong correlation between a bone's architectural properties and the mechanical forces that it experiences. Mechanical load perturbs interstitial fluid. Upon detecting these perturbations, osteocytes which are embedded deep within mineralised bone remotely coordinate the adaptive response by directing the actions of effector cells such as bone-forming osteblasts and bone-resorbing osteoclasts. Osteocytic cells detect and communicate biophysical signals to osteoblasts and also enhance the signal enabling osteoblasts to rapidly respond to a signal that they cannot themselves detect (Taylor et al. 2007). The following rules govern bone adaptation: 1/ it is driven by dynamic rather than static loading, 2/ only a short duration of mechanical loading is necessary to initiate an adaptive response, 3/ bone cells accommodate to a customary mechanical environment making them less responsive to routine loading signals (Turner 1998). The best osteogenic response will be achieved by dynamic weight-bearing activity, in specific if the mechanical load is repeated regularly and influences the skeleton by high muscle strains in various directions (American College of Sports Medicine 2004). Thus, training programs including jumps have considerable higher effect on bone mass than cycling or swimming loading (Bassey et al. 1994, Bassey et al. 1998, Heinonen et al. 1996). Both gravity and the pull of the muscles are necessary for

stimulating bone mass. This is obvious in astronauts who have deteriorated bone mineralisation after some weeks of weightlessness (Am College of Sports Medicine 2004). Absence of physical activity and loading such as being confined to bed for a long period will negatively affect the trabecular and cortical bone in the weight-bearing parts of the skeleton (the vertebrae, the hip and the pelvis). A study found that the decrements in bone mineral density were not fully reversed after 6 months of normal weight-bearing activity (Bloomfield 1997, The Swedish Council on Technology Assessment in Health Care 2003). Physical activity can increase peak bone mass in young people, reduce age-related bone loss and might also increase bone mass some percentages in the elderly (Heaney 1998, Marcus 2001). Healthy adults benefit from strength training at high intensity and jumps, which mean high muscle strains and great loading (Bassey et al. 1994, Bassey et al. 1998, Heinonen et al. 1996). Premenopausal women who performed 50 vertical jump once a day for half a year increased bone mineral density at the greater trochanter (Bassey et al. 1994, Bassey et al. 1998). In another study premenopausal women who performed various jumps 3 times a week for 18 months increased bone mineral density at the femur, the femoral neck and the lumbar spine (Heinonen et al. 1996). In premenopausal women (aged 35-40 years) bone mineral density at the hip was improved by high intensity aerobics for one year (Vainionpää et al. 2006). In healthy women aged 50-59 years the natural progression of thoracic kyphosis may be prevented by back extension exercises performed 3 times a week for 1 year (Ball et al. 2009). A dose-response association has been found between physical activity level and the risk of a hip fracture. There is about 30-40% lower hip fracture incidence amongst physically active elderly compared to physically inactive. The decrease in fracture incidence in the elderly by being physically active is probably caused by the improvement of muscle strength, bone mass and balance performance (American College of Sports Medicine 2004, Englund et al. 2005, Gregg et al. 2000, Høidrup et al. 2001, Järvinen et al. 2008, Jessup et al. 2003, Joakimsen et al. 1997, Korpelainen et al. 2006, Pfeifer et al. 2004). Thus, the prevention of fractures should focus both on the prevention of osteoporosis and on the prevention of falls (Järvinen et al. 2008).

Rehabilitation training and physical activity for osteoporotic persons

Osteoporotic patients need adequate and skilled supervision for their individual rehabilitation and training. A knowledgeable physiotherapist can motivate fragile persons to begin exercising not only for the rehabilitation period of a fracture, but also to become physically active for all their life. Correct supervision, feedback, and follow-ups are extremely important to encourage further physical activity in osteoporotic patients. Strength training of moderate intensity and balance exercises are beneficial for most osteoporotic persons (American College of Sports Medicine 2004). It is important to begin an exercise session with a gentle 10-minute warm-up (Karinkanta et al. 2007, Khan et al. 2001). Weight-bearing exercises, which are performed in stable positions, are adequate for fragile persons. The exercises should be safe to minimise the risk of arthritic complications, falls and fractures. It is important that the physiotherapist individualises the loading when training equipment and weights are used (Englund et al. 2005, Grahn Kronhed et al. 1998, Hourigan et al. 2008, Malmros et al. 1998). The loading should be site-specific and be increased progressively to attain the best possible effect on bone mass (Layne 1999, Marcus 2001). In a training study with osteopenic/osteoporotic women (mean age 73 years), the intensity of the training stimulus was set at 50-60% of one repetition maximum (1RM) using 2 sets and 10-15 repetitions. Thereafter, the intensity progressed to 70-80% of 1RM with 3 sets and 8-10 repetitions. After one year of combined resistance and balance-jumping training physical function, dynamic balance and muscle strength of the lower limbs were improved (Karinkanta et al. 2007).

In the acute phase of a vertebral fracture pain might induce reflex inhibition resulting in overuse of spinal flexors. Vertebral fractures may cause postural deformities such as hyperkyphotic changes in the spine with inappropriate stretching of ligaments and thus leading to chronic back pain. Multiple vertebral fractures, severe kyphosis and height loss may lead to iliocostal contact, resulting in iliocostal friction syndrome and flank pain (Arden et al. 1998, Eastell 1998, Francis et al. 2008, Hallberg et al. 2004, Lips 1998, Malmros et al. 1998). Severe vertebral fractures in the thoracic spine result in decreased lung capacity, which may result in respiratory symptoms. Vertebral fractures in the lumbar spine result in decreased abdominal volume and causes the abdomen to protrude (Eastell 1998). A spinal orthosis might decrease the kyphotic angle, reduce pain and improve quality of life (Pfeifer et al. 2004). Body height loss is a strong indicator of vertebral deformities caused by vertebral fractures or degenerative changes in the intervertebral discs (Eastell 1998). The importance of measuring body height and inquiring body height in early adult life should be emphasised for physiotherapists working in the clinic to get an eventual hint of possible osteporotic vertebral osteoporosis (Moayyeri et al. 2008). Physical activity is beneficial for pain relief and an obvious effect was found in osteoporotic women suffering from backache (Malmros et al. 1998). Performing isometric contraction of paraspinal muscles might decrease post vertebral fracture pain and oedema. Physiotherapists should supervise osteoporotic persons to perform back strengthening exercises for instance ”back-ups” lying prone (with a pillow under the stomach) and raising the upper part of the body a bit from the surface without the support of the arms, in order to improve muscle strength, vertebral bone mass, and to relieve back pain. Such back strengthening exercises may help to reduce the risk of further vertebral fractures (Francis et al. 2008, Hongo et al. 2007, Malmros et al. 1998, Sinaki et al. 2002). Flexion exercises such as “sit-ups” should be largely avoided, and also trunk rotation exercises might be harmful and may increase the risk of vertebral compression in osteoporotic persons (Francis et al. 2008, Sinaki and Mikkelsen 1984). Middle-aged postmenopausal women, who performed 10 back extension exercises (”back-ups”) at each training session 5 days/week for a 2-year period and were free to continue in any self-selected physical activities for another 8 years had significant fewer vertebral compressions compared to a control group at a 10-year follow-up (Sinaki et al. 2002). Similar home-training back extension exercises for 4 months improved both back muscle strength and HRQL in postmenopausal osteoporotic women (Hongo et al. 2007). Other adequate home-training programs are exercises which are performed in stable positions e.g. positioned on the knees and hands (“all fours”) and trying to lift one arm and the opposite leg simultaneously while holding in a diagonal, standing with the palms placed against the neck or at the hips and simultaneously forcing the elbows back and straightening the back, and rising from a stable chair without using the arms (Albertsson et al. 2007, Kalapotharakos et al. 2005, Khan et al. 2001). A home-training program including such exercises improved muscle strength, mobility, and also quality of life in osteopenic/osteoporotic postmenopausal women who performed the exercises regularly 7 days/week for 12 weeks (Chien et al. 2005).

Decreased muscle strength and deteriorated vestibularis function are important causes to impaired balance ability and increased frequency of falls amongst the elderly (Frischknecht 1998, Kristinsdottir et al. 2000, Low Choy et al. 2007, Ödkvist et al. 1998, Rosenhall and Rubin 1975). Age-related changes are found both in strength and somatosensation at the age of 50-60 years (Low Choy et al. 2007). Postural sway during quiet standing has been found to increase with each decade of life in healthy adults aged 40-80 years (Vandervoort et al. 1990). The vestibular system shows a reduction in function, with a loss of 40% of the vestibular hair and nerve cells at the age of 70 years (Rosenhall and Rubin 1975). Falls generally result from

an interaction of multiple and diverse risk factors and situations. Age, disease, and the presence of environmental hazards influence the incidence of falls and the severity of fall injuries. A fall should be defined as “an unexpected event in which a person comes to rest on the ground, floor, or lower level.” A person should be asked, “In the past month, have you had any fall including a slip or trip in which you lost your balance and landed on the floor or ground or lower level?” (Lamb et al. 2005).

Persons reporting a single fall should be observed, when rising from a chair without using their arms (Albertsson et al. 2007). Those persons who have sustained a fracture should be thoroughly tested for balance ability by physiotherapists. The Falls Efficacy Scale-International (FES-I) and the Short FES-I are good and feasible measurements to assess fear of falling in older persons (Kempen et al. 2008, www.profane.eu.org). The assessment by Timed Up&Go can quantify basic mobility in older persons. Other risk factors for falls should be identified (American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention 2001, Lundin-Olsson et al. 1998, Podsiadlo et al. 1991).

Balance performance can be improved considerable at high ages by strength training of the lower extremities and by specific training which is directed towards stimulating of the sensory systems (visual, vestibular and somatosenory) and their central integration (Grahn Kronhed et al. 2001, Kammerlind et al. 2001). Balance exercises can be performed in a training group by walking around and changing direction eventually combined by turning head or moving eyes, whole-body rotation 360°, walking on tiptoes and on heels, walking forward (heel to toe) and walking backward (toe to heel) on a line, jogging around a chair and turning to the left or right on command, standing on a foam support with the eyes open and closed, rising from the sitting to standing position and bowing to the left or right, exercising on balance boards, and also by various ball exercises (Ekvall Hansson 2007, Grahn Kronhed et al. 2001, Kammerlind et al. 2001, Madureira et al. 2007). Home exercises can be performed standing in a corner (eventual with the back of a chair placed close to the person to prevent falls) with both feet together on a firm or a foam support and trying to close the eyes for one minute, standing on one leg with the eyes open for half a minute if possible, rising up on toes 5-20 times, and careful knee bends 5-20 times (eventual holding on the back of a chair) (Albertsson 2007). Regularly participation in Tai Chi or in balance training groups have decreased risk for falls and falls injuries among the participants (American College of Sports Medicine 2004, Bean et al. 2004, Howe et al. 2007, Kannus et al. 2005, Madureira et al. 2007). Linedance is proposed as adequate training for postmenopausal women due to positive effects on balance performance (Shigematsu and Okura 2006, Young et al. 2007).

According to a consensus statement the recommendation for promoting health runs: ”In all ages, people should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week” (Pate 1995, US Department of Health and Human Services 1996). However, people suffering from established osteoporosis are recommended to walk at a quiet pace. An increased risk of falls associated to brisk walks (progressively increased pace) was found in women (mean age 66 years) with a previous humerus fracture since 2 years (Ebrahim et al. 1997).

After a period of inactivity (for instance after a healed fracture) it is extremely important that physiotherapists encourage osteoporotic patients to practise physical activity regularly in order to reduce their risk for falling accidents, dependence and helplessness. In women (mean age 68 years) with a recent fall-related distal forearm fracture a decline was found concerning

walking capacity and hand grip strength on the non-fractured side the first year after fracture. Though the patients were apparently healthy they exhibited risk factors for new falls and fractures. Thus, it is important to screen patients with a previous fracture for fall and fracture risk and targeted them for preventive measures besides fracture treatment (Nordell et al. 2005). Physiotherapists should play a major role in maintaining and improving general physical functions in osteoporotic patients. Furthermore, the use of a physical activity referral (PAR) scheme may improve physical activity level in patients visiting primary health care centres (Leijon et al. 2008).

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