Exercise and Osteoporosis

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Osteoporosis is a major public health problem of the elderly, especially postmenopausal women; it demands effective strategies for prevention and treatment. Bone mineral density (BMD) has been shown to decrease in response to physical inactivity which leads to increased risk of osteoporotic fractures. Studies in animals show that bone has enhanced physical and mechanical properties following periods of increased stress at specific skeletal sites. Bone adapts to mechanical loading or weight-bearing exercise by increasing bone mass. Cross-sectional studies in humans show that physically active subjects have significant higher bone mineral density than age-matched sedentary controls. Moreover, athletes have greater bone mineral densities of the dominant playing limb than in their non-dominant counterpart. Because of the inherent bias in cross-sectional studies, the questions on the effect of exercise training may only be answered by longitudinal studies. Longitudinal or intervention studies suggest that resistance training with high intensity and low repetitions can increase bone mineral density, particularly in the site-specific loading training. Furthermore, walking or weight bearing exercise is currently recommended because of its greatest compliance. However, further research is needed to establish an appropriate exercise prescription for preventive and therapeutic training programs for postmenopausal women.

Keywords : *Osteoporosis, Postmenopausal women, Exercise.*

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Objective : 1. To describe animal studies and human studies involving with exercise in Osteoporosis,

2. To review research evidences that summarize the effectiveness of various types of exercise in preventing bone loss in postmenopausal women.

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ภาวะกระดูกพรุนเป็นภาวะที่ร่างกายมีความหนาแน่นของเนื้อกระดูกลดลง ซึ่งพบได้มากในสตรีวัยหลังหมดประจำเดือน โรคนี้จัดเป็นปัญหาสำคัญทางสาธารณสุขปัญหาหนึ่งที่ควรมีมาตรการป้องกันและมีวิธีการรักษาที่มีประสิทธิภาพ เพราะการที่ความหนาแน่นของเนื้อกระดูกลดลงนั้นอาจนำไปสู่การเกิดกระดูกหักในตำแหน่งที่มีกระดูกพรุนได้โดยง่าย การศึกษาในสัตว์ทดลองแสดงให้เห็นว่าคุณสมบัติของกระดูกทั้งทางกายภาพและทางกลศาสตร์จะดีขึ้นหลังจากที่กระดูกได้รับแรงกระทำ ณ ตำแหน่งใดตำแหน่งหนึ่งเป็นระยะเวลาที่นานเพียงพอ โดยความหนาแน่นของเนื้อกระดูกจะเพิ่มขึ้นเพื่อตอบสนองต่อแรงที่มากระทำนั้น ส่วนการศึกษาในมนุษย์สามารถแบ่งประเภทออกเป็นการศึกษาแบบภาคตัดขวางและการศึกษาแบบทดลองเพื่อติดตามผล ในการศึกษาแบบภาคตัดขวาง พบว่าผู้ที่มีกิจกรรมทางกายอยู่เสมอจะมีความหนาแน่นของเนื้อกระดูกสูงกว่าผู้ที่อยู่ในวัยเดียวกันแต่มีกิจกรรมทางกายน้อย นอกจากนี้ ในนักกีฬาคนเดียวกัน จะพบว่าแขนข้างถนัดที่ใช้ในการเล่นกีฬาจะมีความหนาแน่นของกระดูกมากกว่าแขนข้างที่ไม่ถนัด ส่วนผลของการศึกษาแบบทดลองชี้ให้เห็นว่าการออกกำลังกายแบบมีแรงต้าน โดยใช้แรงต้านมากและทำจำนวนครั้งน้อยๆ โดยฝึกโดยตรง ณ ตำแหน่งที่ต้องการ จะสามารถเพิ่มความหนาแน่นของกระดูก ณ ตำแหน่งนั้นได้ นอกจากนี้ มีการศึกษาที่สนับสนุนให้สตรีที่มีภาวะกระดูกพรุนใช้การเดินหรือการออกกำลังกายแบบลงน้ำหนัก เนื่องจากเป็นวิธีการออกกำลังกายที่ง่าย สะดวก และสามารถปฏิบัติได้อย่างสม่ำเสมอ อย่างไรก็ตาม ยังคงต้องมีการศึกษาวิจัยกันต่อไปเพื่อหาข้อสรุปเกี่ยวกับรูปแบบการออกกำลังกายที่เหมาะสมที่สุดสำหรับสตรีที่มีภาวะโรคนี้

คำสำคัญ : กระดูกพรุน, สตรีวัยหลังหมดประจำเดือน, ออกกำลังกาย

Osteoporosis is a disorder of the skeleton characterized by low bone density and micro-architectural deterioration of bony tissue. This results in an increase in fracture risk.[1] Osteoporosis and osteopenia* are major public health problems in today's society.[2-3] The World Health Organization has defined osteoporosis as a condition of the bone in which the bone mineral density (BMD) is lower than 2.5 SD or more below the young adult mean (T-score at or below -2.5). Osteopenia is defined when BMD is between 1 and 2.5 SD below the young adult mean (t-score at or below -2.5), whereas normal BMD is defined as BMD between 2.5 SD above the young adult mean and one SD below the young adult mean.[4] Risk factors for osteoporosis include age, prior fractures, hypogonadism, estrogen use, glucocorticoid use, smoking, alcohol intake, low body weight and family history of osteoporotic fracture.[5]

It has been reported that there is a steep rise in the incidence of osteoporotic fractures with age and there is a higher incidence in women than in men.[6] Prevention of osteoporotic-related fractures is dependent on the ability to detect low bone mass within individuals, including women who are asymptomatic.[7] In women with secondary amenorrhoea, the peak bone mass is reduced and the risk of osteoporosis is increased. Peak bone mass is also reduced by late menarche. Premature menopause, especially before the age of 45, is a strong determinant of bone loss and increased risk of fracture among women.[6] Rapid bone loss at the start of the menopause is also an important contributing factor to the development of osteoporosis.[8] The rate of bone loss dramatically increases during the first ten years of menopause. It has been estimated to be 2-5 % per year.[9] Women with postmenopausal osteoporosis lose trabecular bone at an accelerated rate (three times the rate of normal losses.[10]

Treatment of osteoporosis involves the use of either anti-resorptive (e.g. estrogen, bisphosphonate) or bone formation agents (e.g. parathyroid hormone). Lifestyle changes should be encouraged including adequate calcium and vitamin D intake, maximizing physical activity, and reducing falls.[5] Certain types of exercise have been found to exert moderate benefits on BMD of the hip, spine, and wrists, the sites that are normally affected by osteoporosis.[11]

Exercise has been recommended as an effective strategy in the prevention of or treatment for bone loss after menopause. Although participation in an exercise program may be time-consuming and needs consistent effort, it has certain clear advantages, such as low cost and freedom from negative side effects and the presence of positive side-effects.[12] In particular, the prevention of osteoporosis is vital, because there is no efficient treatment once the bone architecture has deteriorated to the point of fracture. Evidence that exercise is osteogenic and can reduce the incidence of osteoporotic fracture has conclusively demonstrated in the number of studies.[13] It is widely accepted that exercise can increase or maintain BMD, but the exact mechanism is still unknown, as are the specifications of effective exercise programs in terms of site of application, intensity, frequency and duration. As such, several studies in animals and human subjects were conducted in the area of osteoporosis

* A term used by radiologists to indicate that the bones on a plain x-ray film appear to be of decreased mineral content

to examine how the physical and mechanical properties of bone change with exercise, and which exercise regimens are most effective in enhancing bone formation. In addition, it is possible to study the mechanical and chemical properties of bone directly in animal skeleton and apply the knowledge gained from animal studies to human studies.

Studies in animals

The key variables associated with exercise for bone formation are: strain magnitude, strain rate, strain distribution, number of strain cycles, dynamic strain and applied load.[14-15] Animal models have been used to determine the adaptive response of bone to mechanical stimulation in a controlled environment. Obviously, some experimental protocols are performed more easily on animals than on human beings. However, one must be aware of the possible short comings of the findings derived from animal studies, in terms of the difficulty in directly comparing and extrapolating findings to humans. Moreover, the intensity of exercise and age of the animals remain significant to determine the effects of exercise on bone.

Model of external loading

One of the techniques of loading bones *in vivo* is to apply artificial external loads. Bone mass can be generated at a particular site by controlling the strains produced within the bone tissue. The results have shown that a greater amount of bone formation occurs when bone is subjected to progressively greater magnitudes of strain with relatively few loading cycles (as few as 36 per day).[15-16] This suggests that the adaptive process within the skeleton can be engendered by comparatively infrequent loading events rather than requiring long periods of repetitive activity.[14] Moreover, bone can respond to changes in strain distribution. When the strain distribution is altered, new bone is deposited to compensate for the structural loss. This indicates that, the prime objective of bone's adaptive remodeling is to produce a mass and arrangement of the skeletal tissue in which can withstand the functional demands placed on it.

Based on these studies and others, it can be concluded that if strains are dynamic, high in magnitude, high in rate and of abnormal distribution, a substantial osteogenic response can be achieved after remarkably few loading cycles.

Model of weight bearing exercise

The most frequently used method of weight bearing exercise in animals is aerobic exercise, primarily treadmill running.[17-19] Several studies have indicated that bone adapts to prolonged weight bearing exercise by increasing bone mineral density, increasing cortical bone area, and increasing stiffness. However, results of running studies on BMD in animal models have been equivocal, i.e., varied and inconclusive. It has been shown that running might increase bone calcium and bone volume, but no change in bone density in swine.[17] One of the primary limitation in the study of the effect of aerobic exercise on BMD is the unavoidable systemic effects; such programs have their potential for either potentiating or reducing the benefits of mechanical loading on bone.[20]

Other limitations in these studies included complex interactions between bone remodeling and exercise intensity, exercise duration, animal species, and skeletal age. Furthermore, these conflicting findings show that aerobic-type exercise is probably not the optimal mode for increasing bone mass and more weight training studies should be carried out.

Model of disuse osteoporosis

Loss of mechanical loading caused by immobilization and paralysis in animals has been studied to determine the effect of disuse osteoporosis. After immobilization, the rats' bones are significantly decreased in comparison to age-matched controls.[21-22] The loss occurred earlier in the animals on a calcium-deficient diet [22] or the animals in the absence of the thyroid and parathyroid glands.[21] Particularly, the bone loss was much more severe in the weight-supporting bones. These studies suggested that the reduced bone mass was caused by an increase in bone resorption and a decrease in bone formation. In paraplegic rats, lower bone calcium content was found, indicating that bone deposition had slowed down and perhaps that resorption had occurred.[23] Similarly, a study in rats that were subjected to simulated weightlessness has shown that there was reduced activity of the osteoblasts in the long bones. This suggests that the lack of mechanical stress somehow 'signal' the osteoblasts not to function in their normal activity.[24]

In conclusion, studies in animals show that increased bone mass can result from increased stress at specific skeletal sites. Strains which are high in rate and magnitude, and of abnormal distribution, but not necessarily long in duration, are best for inducing new bone formation, resulting in the strengthening of bone by increasing its density. From the results of these studies, it can be concluded that optimal exercise regimen designed to increase bone mass and strength should involve loads of high magnitude and rate, should be dynamic and involve a varied pattern of stress. Relatively few cycles of loading per day (approximately 36 cycles) would be required, so the exercise would not have to be long in duration. Also, the exercise program should be performed regularly to avoid reversibility due to disuse or inactivity.

Studies in humans

The majority of evidences support that exercise is a preventive strategy for osteoporosis has accumulated from cross-sectional research. Most studies have focused on relationships between activity patterns, parameters of fitness, or athletic status. Cross-sectional studies provide results which reflect the effect of habitual loading pattern on bone status, while longitudinal studies produce more definitive findings gained from the exercise intervention. However, intervention studies are somewhat more difficult because it takes a longer time before changes of bone may be detected.

Cross-sectional studies

Basically, two types of studies have been undertaken to test the hypothesis that increased physical activity is associated with higher BMD. Some studies investigated the effect of unilateral activity on limbs of the same individuals, while other studies compared athletes and sedentary controls or individuals with varying background of physical activity.

Unilateral limb model

In the studies of unilateral limb model, there was considerable evidence that physical activity had positive influence on BMD.[25-26] Several studies have demonstrated greater bone mass in the bones of the arm and forearm on the dominant side in professional tennis players or those who have played regularly throughout their life. These findings suggest that the adaptation of increased bone mass is in response to habitual physical activity that is specific to the site of stress and not mediated by a systemic effect.

Comparative studies of different athletes with sedentary populations

Recent cross-sectional studies of athletic groups show that participants in high impact sports such as gymnastics, basketball, and netball, and medium impact sports such as running, and field hockey have significantly greater BMD than players of non-impact sports such as swimming, and non-athletic groups.[27-28] Mechanical loading appears to be a key factor in this relationship. Studies have examined gymnasts, swimmers, and sedentary individuals have demonstrated greater BMD per unit increase in body weight was more among gymnasts than amongst swimmers or sedentary individuals.[27, 29-30] Further study has shown a positive relationship between muscle strength and BMD in young wrestlers, basketball players and tennis players.[31] These results suggest that high-impact bone loading activities may lead to increased BMD in athletes.

Other cross-sectional studies

Studies on various non-athletic groups e.g. young women, premenopausal women and men have demonstrated a positive correlation between bone mass and the level of daily physical activity.[32-35] Some studies support the concept that the dominant factor in daily physical activity relating to BMD is site specific, high loading activities, e.g. prolonged daily walking can increase calcaneal BMD. However, extreme exercise, too little or excessive, may both result in bone loss. Amenorrheic athletes, particularly those in endurance sports, have been found to have a lower BMD than matched groups of eumenorrheic athletes.[36-37] A previous study has shown that the BMD of the amenorrheic women's lumbar spine was 88 % of the eumenorrheic women's value.[37] Reduction of activity in female athletes can produce eumenorrhea. The resumption of menses, in turn, contributes to the significant increase in the vertebral BMD of the formerly amenorrheic athletes.[38]

The relationship between muscle strength and BMD in anatomically related areas in human subjects was also studied. It has been demonstrated that the elbow extensor peak torque is significantly associated with radial BMD in men and women.[39] This relationship may reflect compressional loading that occurs along the radius when the *triceps brachii* are used during concentric (e.g. pushing) or eccentric contractions (e.g. lowering the body). These studies suggested that muscle strength may be a factor in the determination of BMD in weight bearing sites. However, other studies could not find a correlation between muscle strength and bone mass. This may be a result of the limitation of cross-sectional studies.

Although cross-sectional studies have correlated physical activity or associated factors with bone mass, it cannot demonstrate a cause-effect relationship. The most convincing evidence linking exercise and bone mass comes from controlled prospective intervention studies, as discussed in the following section.

Intervention studies

Since problems associated with osteoporosis are mostly found in postmenopausal women, a number

Table 1. Randomized controlled trials of aerobic / weight bearing exercises for postmenopausal women.

Reference	Subject [a]	Bone site, Measurement method[b]	Training description [c]	Results [d]
Grove et al. (1992) [44]	E 10 C 5	Lumbar - DPA	High and low impact aerobics 3 x /w, 20 min., 12 months.	Exercise groups maintained BMD
Lau et al. (1992) [45]	E 15 C 12	Lumbar Femur - DXA	100 x stepping up and down a block + 15 min. exercise moving the upper trunk 4 x /w, 10 months	Changing in BMD LS: E: 1.32%, C: -0.1% FN: E: 6.0%, C: -4.2%
Hatori et al. (1993) [46]	M 9 H 12 C 9	Lumbar - DXA	M: 3 x /w 30 min., 7 months walking at 90% of the HR at anaerobic threshold H: 3 x /w 30 min., 7 months walking at 110% of the HR at anaerobic threshold	Changing in lumbar BMD M: -1.71% H: 1.89% C: -2.91%
Bassey & Ramsdale (1995) [47]	E 20 C 24	Lumbar Femoral neck, - DXA	E: 1 x /w high impact exercise + 50 heel drops/day at home C: 1 x /w low impact exercise + flexibility exercise at home	Changing in BMD LS: E: -3.4%, C: -1.0% FN: E: 0.1%, C: -0.79%
Prince et al. (1995) [48]	E 42 C 42	Lumbar Femur - DXA	Weight bearing exercise 2h/w + walking 2h/w at 60%HR_{max}, 24 months	Changing in BMD LS: E: 0.76%, C: -0.1% FN: E: 0.28%, C:-0.18%
Bravo et al. (1996) [49]	E 61 C 63	Lumbar Femur - DXA	Weight bearing activities 1h 3 x /w at 60-70% HRR + flexibility exercise	Changing in BMD LS: E: 0.55%, C: -1.29% FN: E: 0.27%, C:-0.40%

[a] E = exercise group; C = control group; M = moderate-intensity training group; H = high-intensity training group;
[b] DPA = dual photon absorptiometry; DXA = dual-energy X-ray absorptiometry
[c] h/w = hour per week; x /w = times per week; min. = minutes; HR_{max} = maximal heart rate; HRR = heart rate reserve
[d] BMD = bone mineral density; NS = nonsignificant; FN = femoral neck; LS = lumbar spine; RD = radius, % = % change per year

of longitudinal exercise studies measuring BMD in postmenopausal women have been conducted to investigate the effect of exercise on bone mass. Unfortunately, narrative reviews of such studies mostly come to a conclusion that exercise training programs may maintain or improve the bone mass or provide conflicting results.[40-41] The inconsistent results of the narrative reviews is probably due to the fact that those reviews mostly included both non-randomized controlled trials and randomized controlled trials (RCTs). Since non-randomized controlled trials can introduce confounding factors e.g. self-selection, convincing evidence for the effect of exercise thus comes from RCTs which offer the best possibility for a valid evaluation of the treatment outcome.[40] To date, a few studies of systematic review and meta-analyses of RCTs that examine the effect of exercise training programs on bone mass have been published.[7, 40-43] The number of RCTs included in these systematic reviews varied from 12 trials [43] to 18 trials.[7, 40] The exercise training programs included aerobic, strengthening, resistance or weight-bearing exercise. Relevant RCTs are summarized in Table 1 and 2.

Table 2. Randomized controlled trials of resistance exercises for postmenopausal women.

Reference	Subject [a]	Bone site, Measurement method[b]	Training description [c]	Results [d]
Sinaki et al. (1989) [52]	E 17 C 18	Lumbar - DPA	Back strengthening exercise.: at home 5 x /w, 24 months.	Rates of bone loss between C and E, NS.
Notelovitz et al. (1991) [53]	E 9 C 11	Lumbar - DPA	Resistance training 5 stations 8 RM 3 x /w 15-20 min., 12 months.	Change in lumbar BMD LS: E: 8.3%, C: 1.5%
Nelson et al. (1994) [54]	E 20 C 19	Lumbar Femur - DXA	High-intensity strength training, various exercises 3 sets of 8 reps. at 80% 1 RM 2 x /w 45 min. , 12 months	Changing in BMD LS: E: 1.0%, C: -1.8% FN: E: 0.9%, C: -2.5%
Pruitt et al. (1995) [55]	L 7 H 8 C 11	Lumbar Femoral neck, - DXA	10 resistance exercises 3x /w 60-75 min., 12 months L: 3 sets 14 reps. at 40% 1 RM H: 1 sets 14 reps. at 40% 1 RM + 2 sets 7 reps. at 80% 1 RM	NS change in lumbar & femoral neck between groups

Table 2. Continuous.

Reference	Subject [a]	Bone site, Measurement method[b]	Training description [c]	Results [d]
Kerr et al. (1996) [51]	E 23 C 23	Femoral neck, Radius - DXA	Unilateral resistance training 3 sets 20 RM exercises of upper and lower limb 3 x /w 20-30 min., 12 months; other site served as control site	Changing in BMD FN: E: 1.7%, C: -0.6% RD: E: 2.4%, C: -1.4%
Kerr et al. (2001) [56]	S 41 F 43 C 42	Lumbar Femur Radius - Hologic 4500	S: nine exercises + resistance F: nine exercise + stationary bicycle riding with minimal load 2 x /w , 24 months	Changing in BMD in S group at hip site

[a] E = exercise group; C = control group; L = low-intensity training group; H = high-intensity training group; S = strength training group; F = fitness group

[b] DPA = dual photon absorptiometry; DXA = dual-energy X-ray absorptiometry

[c] x /w = times per week; RM = repetition maximum; reps. = repetitions; min. = minutes

[d] BMD = bone mineral density; NS = nonsignificant; FN =femoral neck; LS = lumbar spine; RD = radius, % = % change per year

Aerobics / weight bearing exercise

Several studies have used randomized exercise interventions to investigate the effects of aerobic or weight bearing exercise on postmenopausal bone mass, as seen in Table 1.[44-49] Aerobic exercise programs mostly consisted of upper, lower limbs and trunk, a mixture of calisthenics, stretching, strengthening and walking exercises.[7] Few examples of RCTs in this area and their treatment effects are mentioned below.

A 1-year randomized intervention study of weight bearing exercises (walking, stepping up and down from benches), aerobic dancing, and flexibility exercises combined with patient education was conducted in 124 postmenopausal women.[49] The exercise intensity was 60 minutes, three times a week, over a period of 12 months. All subjects attended bi-monthly educational seminars covering topics related to osteoporosis. Spinal and femoral BMD were measured. The results showed that spinal BMD stabilized in the exercisers while decreasing significantly in the controls (P=0.031), but no change in femoral BMD was observed in either group. Moreover, the exercise program produced a significant increase in the functional fitness, well-being, and self-perceived health of the exercisers, and reduced the intensity of back pain.

E.J. Bassey and S.J. Ramsdale (1995) examined the effects of brief daily exercise on BMD in 44 postmenopausal women using weight bearing exercise in a regimen adapted from osteogenic protocols reported in animal studies.[47] The treatment group was required to perform 50 "heel drops" daily at home (raising the body weight onto the toes and then letting it drop to the floor keeping the knees and hips extended) and to attend a weekly class of high-impact activities, while the control group did flexibility exercise and low-impact activities. The sites assessed were spine and femur. The study showed no significant increase after 12 months of exercise at any site in either group. However, there was evidence for a maintenance effect of the exercise in the treatment group, especially BMD of the trochanter ($P<0.01$).

A randomized controlled trial of the effect of calcium supplementation and exercise on bone density in 168 postmenopausal women was carried out.[48] The exercise regimen used in this study consisted of two hours of extra weight bearing exercise per week and 2 hours of walking (at 60 % maximum heart rate) per week over 2 years. BMD was assessed at lumbar spine, hip, and ultradistal site of tibia. The result showed that the calcium and exercise group had less bone loss at the femoral neck site when compared with calcium supplementation alone ($P<0.05$). Nevertheless, there was no significant bone loss at the spine site in any group.

It can be concluded from the available RCTs that aerobic exercise involving weight bearing exercise can maintain or increase bone mass. That is, weight bearing exercise such as dancing, brisk walking, jogging, or jumping can reduce the rate of bone loss in postmenopausal women. A training frequency of 3 days/week at high intensity of at least 12 months tends to result in an increase in BMD. In systematic reviews and meta-analyses, the treatment effects of aerobic and weight bearing exercise consistently occurred at the lumbar spine,[7, 40, 42] femur,[40, 42] and wrist.[7, 42] This supports the notion that this type of exercise may impose necessary strain, strain rates and unusual strain distributions on the bone,[40] and thus the osteogenic response and bone formation occurs. However, some previous studies have demonstrated that non-weight bearing activities can have positive impact on the bone mass.[50-51] These support a hypothesis in which exercise-related factors, other than weight bearing, also influence bone remodeling.

Strengthening or resistance exercise

Strengthening or resistance exercises aimed at causing muscle hypertrophy and other specific loading regimens have been employed in several studies.[51-56] The evidence suggests that this type of exercise is probably more appropriate for osteogenesis than aerobic activities. Human bones can be loaded indirectly via muscle pull, the inherent assumption here is that the muscle pull will create a strain at its attachment site and an osteogenic response will occur. Bones can also be directly loaded by gravity and body weight. Despite this evidence, a relatively small number of RCTs of strength training have been conducted among postmenopausal women. In addition, these studies have varied in terms of methodologies (Table 2).

Two relatively recent well-controlled studies have demonstrated a positive outcome.[54, 56] Nelson and co-workers (1994) studied the effects of high-intensity strength training exercises in 20 postmenopausal women using five different type of exercises compared with untreated controls ($n=19$).[54]

All subjects were sedentary and estrogen-deplete. The results showed that the exercise regimen could significantly increase femoral neck BMD and lumbar spine BMD. Moreover, the exercise helped to improve muscle mass, strength and balance in those women.

Recently, Kerr and co-workers (2001) investigated the effect of a 2-year exercise intervention in three different groups: strength group, fitness group, and non-exercise control. The two exercise groups completed three sets of the same nine exercises, three times a week. While the strength group increased the loading, the fitness group had additional stationary bicycle riding with minimal increase in loading. After 2 years of exercise, a significant increase in BMD at the hip site was found only in the strength group ($P<0.01$). Results of these studies indicated that strength exercise was a feasible means to preserve bone density in postmenopausal women.[56]

Some studies investigated the site specificity of exercise using progressive resistance training program. In the 12-month study, the researchers applied a three weekly high-intensity weight-training regimen (3 x 8 repetition maximum) in 56 postmenopausal women.[51] The resistance exercises were selected to stress the ipsilateral forearm and hip regions. The exercising side was randomly assigned with one side exercise while the alternate side acted as non-exercise control. BMD was measured at the radial forearm and hip sites. The results showed a significant increase in bone mass at the radius and hip sites in the exercise side ($p<0.05$), supporting the hypothesis that site-specific training appeared to be effective in increasing forearm BMD in postmenopausal women. This study also compared the effects of resistance exercise regimen with those of endurance exercise and concluded that postmenopausal bone mass could be significantly increased by a strength regimen that used high-load low repetitions but not by an endurance regimen that used low-load high repetitions.[51] This means the peak load is more important than the number of loading cycles in increasing bone mass in postmenopausal women.

In addition, some intervention studies investigated the effects of exercise in combination with other therapies. In the 1-year study, estrogen therapy was combined with high-intensity strength training 3x per week and statistically and clinically significant increases in BMD were seen at the lumbar spine (8.3%) and the distal forearm (4.1%).[53] Others studies have also examined the effect of estrogen replacement therapy plus exercise on BMD,[57-58] and found that estrogen therapy combined with exercise is more effective than that of either estrogen therapy or exercise alone.

Results from recent systematic reviews and meta-analyses suggest that strength or resistance training has a positive effect on the BMD at the lumbar spine,[7] femur,[41] and radius.[41] In addition, this type of exercise should be used in conjunction with other types of non-pharmacologic and/or pharmacologic therapy to facilitate the highest advantage of preventive and therapeutic program for postmenopausal women.

It can be summarized from the longitudinal studies that exercise-training programs can prevent or reverse bone loss in osteoporotic postmenopausal women. Nevertheless, based on the current evidence, it is not possible to define or recommend an ideal exercise prescription for bone health. The reasons that some human studies could not find a relationship between the training exercise and BMD may be explained by several confounding factors, including body composition, alcohol use, smoking status, diet, physical activity, calcium supplementation, and hormone replacement therapy, as well as compliance bias.[40] Since the effect of the exercises was measured at different sites (e.g. spine, wrist and hip) with different BMD measurements, it is not possible to combine the results from the different studies.[7] Perhaps discrepant results may be explained by major flaws in study designs, such as failure to realize that time sequence is unclear in cross-sectional studies, poor choice of controls in case-control studies, lack of appropriate length of follow-up in prospective intervention studies, and the number of subjects drop-out in such studies. Besides, too small sample size or the use of specialized population that are not representative of any larger population, may be the reason for these different studies. It has been suggested that future researches in this area need to focus on standardized outcome measures, better reporting of all details of exercise prescription and the accuracy of measurement.[7]

Conclusion

Animal studies demonstrate that unusual strain distributions, high strains, and high strain rates stimulate osteogenic response, and thus lead to bone formation. In human studies, however, the level of physical activity is shown to be correlated with bone mass. Evidence supports the existence of a site-specific effect of loading exercises. Activities which are weight-bearing or impact-loading are more likely to stimulate increases in bone mass than non-weight-bearing exercise. Strength training, high-impact exercise and weight-bearing exercise have been proposed as a useful means in the prevention and treatment of bone loss in postmenopausal women. However, the exercise program without an appropriate regimen may result in the ineffective training without any benefit to bone. Exercise program should be attractive and convenience for individuals or groups to follow in order to produce the greatest compliance.

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กิจกรรมการศึกษาต่อเนื่องสำหรับแพทย์

ท่านสามารถได้รับการรับรองอย่างเป็นทางการสำหรับกิจกรรมการศึกษาต่อเนื่องสำหรับแพทย์ กลุ่มที่ 3 ประเภทที่ 23 (ศึกษาด้วยตนเอง) โดยศูนย์การศึกษาต่อเนื่องของแพทย์ จุฬาลงกรณ์มหาวิทยาลัย ตามเกณฑ์ของศูนย์การศึกษาต่อเนื่องของแพทย์แห่งแพทยสภา (ศนพ.) จากการอ่านบทความเรื่อง **"การออกกำลังกายกับภาวะกระดูกพรุน "** โดยตอบคำถามข้างล่างนี้ ที่ท่านคิดว่าถูกต้องโดยใช้แบบฟอร์มคำตอบท้ายคำถาม โดยสามารถตรวจจำนวนเครดิตได้จาก http://www.ccme.or.th

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คำถาม - คำตอบ

1. Which of the following is not considered as a risk factor for osteoporosis ?
   a. prior fractures
   b. alcohol intake
   c. obesity
   d. hypogonadism
2. Which statement is **FALSE** about the management of osteoporosis ?
   a. Prevention of osteoporotic-related fractures is dependent on the ability to detect low bone mass within individuals, including ones who are asymptomatic.
   b. Pharmacological treatment of osteoporosis involves the use of either anti-resorptive or anti-bone formation agents.
   c. Appropriate lifestyle, including adequate calcium and vitamin D intake, maximizing physical activity, and reducing falls should be encouraged in postmenopausal women in order to prevent osteoporotic-related fractures.
   d. High-impact exercises have significant benefits on BMD of the hip, spine, and wrist, the sites that are normally affected by osteoporosis.

✂...

คำตอบ สำหรับบทความเรื่อง **"การออกกำลังกายกับภาวะกระดูกพรุน"**

จุฬาลงกรณ์เวชสาร ปีที่ 48 ฉบับที่ 7 เดือนกรกฎาคม พ.ศ. 2547

รหัสสื่อการศึกษาต่อเนื่อง 3-23-201-9010/0407-(1011)

ชื่อ - นามสกุลผู้ขอ CME credit .... **เลขที่ใบประกอบวิชาชีพเวชกรรม**..............................

ที่อยู่..

1. (a) (b) (c) (d)	4. (a) (b) (c) (d)
2. (a) (b) (c) (d)	5. (a) (b) (c) (d)
3. (a) (b) (c) (d)	

3. Which type of sport that does not lead to increased bone mineral density ?
   a. gymnastics
   b. swimming
   c. basketball
   d. running
4. According to the studies in animals, an optimal exercise regimen designed to increase bone mass should include all characteristics EXCEPT
   a. long duration of exercise session
   b. high strain rate and magnitude
   c. Abnormal strain distribution
   d. Dynamic or intermittent mechanical loading
5. In prescribing an exercise program for patients with osteoporosis, health care professionals should recommend all EXCEPT
   a. High-impact exercises
   b. Strength training exercises
   c. Weight bearing exercises
   d. Low-impact exercises

เฉลย สำหรับบทความ รหัสสื่อการศึกษาต่อเนื่อง 3-23-201-9010/0406-(1009)

1. E   2. E   3. C   4. D   5. C

สำหรับบทความ รหัสสื่อการศึกษาต่อเนื่อง 3-23-201-9010/0406-(1010)

1. ง   2. ค   3. จ   4. ก   5. จ

ท่านที่ประสงค์จะได้รับเครดิตการศึกษาต่อเนื่อง (CME credit)
กรุณาส่งคำตอบพร้อมรายละเอียดของท่านตามแบบฟอร์มด้านหน้า

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