Leaders

Exercise in primary prevention of osteoporosis in women

Current estimates suggest that 25% of all postmenopausal women will suffer from osteoporotic fracture. Prevention is vital, because there is no cure once the bone architecture has deteriorated to the point of fracture with minimal trauma (a working definition of osteoporosis). Evidence that exercise is osteogenic and can reduce the incidence of osteoporotic fracture has accumulated from a number of sources.¹ It is now so widely accepted that blame for the current 'epidemic' of hip fractures has been attributed by some to inactive lifestyles, and there is now concern about inactivity amongst adolescent girls who are at an age when the bone is most responsive. Epidemiological studies have shown significant associations between physical activity and reduced risk of osteoporotic fracture after controlling for other associated variables such as body size, adequate dietary calcium intake and a non-smoking history.^{2 3}

Osteoporotic fracture is usually associated with low bone mineral density, so it is a reasonable assumption that exercise programmes which maintain or increase bone mineral density will reduce fracture risk. Many cross sectional studies confirm that more active lifestyles are associated with higher bone mineral density levels,^{4 5} but these studies inevitably deal with self selected groups and so are vulnerable to bias. More convincing evidence comes from a few well controlled randomised exercise intervention studies with positive outcomes, despite potentially confounding variation in initial bone mineral density, genetic predisposition, systemic hormones, and dietary intake. These studies took from five to 24 months to complete.

Definitions are needed as the word 'exercise' encompasses a wide range of activities. Weight bearing endurance activity such as brisk walking or jogging, the kind of exercise which has reduced coronary heart disease

risk factors, has been evaluated for effect on bone. Jogging or aerobic exercises for 20-30 minutes three times a week has increased lumbar (L1-L4) spinal bone mineral density by 1% in premenopausal women⁶ and maintained or increased it by up to 7% in postmenopausal women⁷⁻⁹ (table). In these older women, bone mineral density in the control group usually decreased. It is assumed that the more vulnerable thoracic vertebrae, which cannot be visualised in absorptiometric scans, also improve along with the lumbar vertebrae. These exercise programmes have not, however, increased bone mineral density at the proximal femur, with the possible exception of one in which the whole trunk region was assessed.⁷ This may be because of lack of power in the studies, as the groups have usually been small and measurements at the femur are less reliable than at the spine.

Weight training programmes based on a totally different kind of exercise (that which increases muscle strength) have also been evaluated. The inherent assumption here is that if the strength of the muscle increases the exercise must have provided an overload, and that the high tensions developed by the muscles pulling on the skeleton will increase its density and strength. The poor mechanical advantage of the musculature ensures that the forces developed in tendons are generally an order of magnitude greater than the external force generated. The outcome of these studies, despite large gains in muscle strength, has not been encouraging in either young,^{6 10} or postmenopausal women (table).¹¹⁻¹⁶ More attention must be paid to the primary stimulus relevant for the bone site of interest; this is probably the local strain produced by the activity.

The mechanical strain theory¹⁷ addresses the fundamental function of bone as a supportive scaffolding

Summary of controlled studies of the response of lumbar spinal bone mineral density to exercise in postmenopausal women; percentage changes from baseline are given if they are significantly different from control; 'maintenance' indicates significant difference from control.

Source	Technique	% Change	n (test + control)	Exercise	Quality
Dynamic exercise					
1983 Krolner <i>et al</i> ⁹	¹⁵³ Gd	Maintained	27	Running etc	Some receiving HRT
1987 Chow <i>et al</i> ⁷	Neut.act.	+7.0	48	Jogging etc	Randomised
1988 Dalsky ⁸	¹⁵³ Gd	+6.1	29	Jogging etc	Some receiving HRT, 1500 mg calcium
1988 Cavanaugh <i>et al</i> ¹⁴	QCT	NS	17	Walking	
1992 Grove <i>et al</i> ¹⁵	¹⁵³ Gd	Maintained	15	Exercises	Randomised, some receiving HRT
1993 Hatori <i>et al</i> ¹⁹	DEXA	NS	33	Walking	Randomised, some receiving HRT
1993 Martin <i>et al</i> ¹⁸	¹⁵³ Gd	NS	55	Walking	1000 mg calcium + vitamin D
Weight training					
1991 Peterson <i>et al</i> ¹¹	¹⁵³ Gd	NS	59	Weights	
1989 Sinaki <i>et al</i> ¹³	¹⁵³ Gd	NS	65	Weights	Randomised
1992 Pruitt <i>et al</i> ¹²	DEXA	+1.6	26	Weights	
1994 Nelson <i>et al</i> ¹⁶	DEXA	Maintained	40	Weights	Randomised
1994 Bassey <i>et al</i> (unpublished)	DEXA	NS	60	Rowing	Randomised, 1500 mg calcium

Techniques: ¹⁵³Gd = photon absorptiometry using gadolinium; Neut.act. = neutron activation; QCT = quantified computer assisted tomography; DEXA = dual energy x ray absorptiometry; HRT = hormone replacement therapy.

which resists gravitational forces and the tension developed by muscles attached to it in order to allow movement. The theory predicts that bone will adapt to increased loads, which produce increased strain, by increasing its strength until the strain diminishes to below an osteogenic threshold on exposure to the same load. Bone is constantly remodelling and so has the potential to change the balance of resorption and deposition, which will result in changes in bone mineral strength and density.

Exercise intended to be osteogenic should therefore provide increased or unusual bone loading, and target specific sites which are vulnerable to fracture. It is disappointing but not surprising, therefore, that neither swimming nor walking at normal rates^{18 19} is beneficial. In water, the body weight is supported and walking probably is too usual an activity. In one study of walking,¹⁹ when the speed was increased to more than 7.2 km/h an increase in spinal bone mineral density was found, but at this speed it is more efficient to run, so the activity must have been race walking rather than normal walking.

Invasive studies using animal models have shown that dramatic osteogenic responses can be achieved in mammalian bone with controlled local loading.^{20 21} They suggest that effective forces are at the top end of the physiological range, rapid in onset and preferably unusual in their strain distribution. They also suggest that quite brief exposure such as 36 cycles of loading applied daily is enough. If this prescription could be translated into voluntary activity suitable for women, its brevity would be appealing in terms of health promotion. It is possible that regular jogging for much less than 30 minutes would have been effective.

The model has been successfully adapted for the radius in postmenopausal women²² and for the proximal femur in premenopausal women.²³ A significant increase of 3.4% in radial bone mineral density was achieved using varied exercises which applied loads in as many directions as possible to the forearm. In the second study, a significant increase of nearly 4% at the trochanter was achieved using 50 daily vertical jumps of average height 8 cm (figure).

Mean changes in trochanteric bone mineral density (BMD) in premenopausal women in response to daily high impact exercise consisting of 50 vertical jumps. The control group was crossed over to join the original test group at six months; both then continued with the high impact exercise. ○ = Test group; ● = control; □ = cross over.

This is not an athletic activity and it takes less than one minute to perform. No other study has so far produced increases in bone mineral density at the femur in women.

This rational approach deserves to be pursued; although the successful studies are few, some of the women participating in them improved by more than 10%;^{7 8 23} notably, these tend to be the ones who had the lowest bone mineral density initially. The outcomes of these studies will help inform public health initiatives and clinical prescription. At present the NHS will not provide bone densitometry for detecting vulnerable individuals, in part because of uncertainty about how to respond to the results. The evidence at present suggests that, in order to optimise bone mineral density and reduce long term fracture risk, varied brief high impact bone loading exercise should be a regular part of a woman's lifestyle from adolescence onwards; this should be as automatic as cleaning the teeth.

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