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ORIGINAL ARTICLE

Positive effects of exercise on falls and fracture risk in osteopenic women

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Abstract

Summary Exercise may affect osteopenic women at risk of falls and fractures. A workstation approach to exercise was evaluated in a randomised study of 98 women. The intervention group improved in measures of balance, strength and bone density. This study supports a preventative exercise approach that aims to reduce risk factors for fractures and falls, in women already at risk, through balance training and weight-bearing activity.

Introduction The objective of this study was to determine the effects of a workstation balance training and weight-bearing exercise program on balance, strength and bone mineral density (BMD) in osteopenic women. A single-blinded randomised controlled trial (RCT) was undertaken for 20 weeks with measurements at baseline and completion.

Materials and methods Ninety-eight (98) community-dwelling osteopenic women aged 41–78 years were recruited through the North Brisbane electoral roll. Subjects were randomised via computer-generated random numbers lists into either a control (receiving no intervention), or exercise group (two one-hour exercise sessions per week for 20 weeks with a trained physiotherapist). Assessments at baseline and post-intervention included balance testing (five measures), strength testing (quadriceps, hip adductors / abductors / external rotators and trunk extensors), and DXA scans (proximal femur and lumbar spine). Baseline assessment showed no significant differences between groups for all demographics and measures except for subjects taking osteoporosis medication. The percentage differences between pre- and post-intervention measurements were examined for group effect by ANOVA using an intention-to-treat protocol.

Results Ninety-eight women (mean age 62.01 years, SD 8.9 years) enrolled in the study. The mean number of classes attended for the 42 participants in the exercise group who completed the program was 28.2 of a possible 40 classes (71%). At the completion of the trial the intervention group showed markedly significant better performances in balance (unilateral and bilateral stance sway measures, lateral reach, timed up and go and step test) ($p<0.05$) with strong positive training effects reflecting improvements of between 10% to 71%. Similarly there were gains in strength of the hip muscles (abductors, adductors, and external rotators), quadriceps and trunk extensors with training effects between 9% and 23%.

Conclusions Specific workstation exercises can significantly improve balance and strength in osteopenic women. This type of training may also positively influence bone density although further study is required with intervention over a

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longer period. A preventative exercise program may reduce the risk of falls and fractures in osteopenic women already at risk.

Keywords Balance · Bone mineral density · Exercise · Osteopenia · Strength

Introduction

The incidence of fractures increases with age, and the total age-standardised incidence of low-trauma fractures seems to be rising in many elderly populations [1, 2]. The total number of fractures occurring worldwide is increasing as the aged population increases. Fracture consequences are a frequent and important cause of disability, increased risk of death and high medical costs [3]. As such, the prevention of fractures is of paramount importance.

Fracture risk is a function of both traumas sustained (often via falls) and bone strength, which is related to both the amount of bone and its structure. Bone mass is assessed through measurement of bone mineral density (BMD) which serves as a good predictor of fracture risk. Each standard deviation decrease in BMD is associated with at least a twofold increase in the risk of fracture [4]. An expert panel of the World Health Organisation proposed that osteoporosis be defined as BMD values more than 2.5 standard deviations below those of young adult females (T score ≤ -2.5), and that osteopenia is defined as values between 1 and 2.5 standard deviations below normal (T score between −1 to −2.5) [5]. In Australia, about 11% of men and 27% of women aged 60 or over are osteoporotic, and another 42% of men and 51% of women are osteopenic [6].

A preventative clinical approach which examines and treats a combination of fall and fracture-related risk factors in persons at risk, may be quite appropriate as epidemiological research has shown that these combinations may predict hip fractures associated with osteopenia and osteoporosis [1]. Poor physical performance and declines in balance and strength have been identified as independent risk factors for falls in previous research [7, 8]. Low bone mineral density is arguably still the best single predictor of fracture [1].

Remodelling of bone occurs in response to physical stress, or lack thereof, where bone is deposited in sites subjected to stress and is resorbed from sites where there is little stress [9]. It is, therefore, important in exercise programs to target appropriate sites which are at increased risk of fracture due to decreased bone density. The sites which have the greatest number of osteoporotic-related fractures are the spine, femur and radius.

Research into the effects of exercise interventions on osteoporosis, osteopenia and fracture risk has historically primarily focused on bone density alone [10]. In addition, a systematic review of trials of exercise for osteoporotic women reported that many had study design limitations [11]. More recent research [12–15] has indicated that balance, strength and bone density may be modifiable through correctly prescribed physical activity. A majority of the completed research focuses on weight-lifting exercise, or the application of external means of adding resistance. However there is a difference between resistance training using weight lifting as opposed to *weight-bearing* exercise, and this is a differentiating factor in this research.

The exercise intervention designed for the study reported herein was developed based on previous work in the fields of physiotherapy, exercise physiology, balance training, bone mechanics, joint stability and anti-gravity musculature. The concepts behind the design of a program targeting balance, strength, bone density and falls prevention included the following. The exercise should be weight bearing as opposed to weight lifting, utilising body weight and gravity to provide resistance training. Many workstations should include functional movements that are closed chain in nature which increase proprioceptive, gravitational and load-related cues through contact of a body part with a supporting surface. All exercises must consider safety to minimise the risk of traumatic fractures, stress injuries and arthritic complications and be age-appropriate. The exercises must be site specific and utilise multi-directional axis of movement (to load bone in all directions and promote osteoblastic activity with respect to all directions of trabeculae). In accordance with fundamental principles of exercise prescription the program must be novel, stimulative by overloading systems above usual activities, be relatively easy to learn, affordable and enjoyable. Finally, specific exercises were to be included which employed the use of the deep trunk stabilising muscles whose importance is becoming increasingly evident in injury prevention but also in this instance because of the attachment of these muscles and the forces imparted to the lumbar spine [16]. It was envisaged that this program would be adapted to home or community settings so it needed to be simple and flexible.

As fracture risk has been related to poor balance, strength and BMD in previous literature, it was foreseen that improvements in these measures would benefit women at increased risk of fracture through osteopenia. The intervention developed and utilised in this study is aimed at risk factors that are specific for fracture, falls prevention and the population of osteopenic women, it targets a condition that is of high prevalence in the community and uses outcome measures that are mostly easy to assess by clinicians.

Our hypothesis in this study was that a 20-week program of structured balance training and weight-bearing exercises delivered via workstation format would provide beneficial effects on three factors associated with fractures: balance, strength and bone density, in community-dwelling women with osteopenia.

Methods

Participants

The sample comprised women with osteopenia who were living independently in the community. The women, who were recruited from the North Brisbane electoral roll, initially volunteered for another study on osteoporosis and thus had recent DXA scans all performed by one radiology centre. Eligibility assessment was completed by phone interview after subjects were invited by letter to participate. Eligibility criteria necessitated women being diagnosed recently (within 6 months) with osteopenia by DXA scan T score between −1.0 and −2.5) and be aged between 40 and 80 years. Subjects were excluded if they had any neuromuscular, skeletal or cardiovascular pathology that precluded them attending or taking part in the exercise program or if they could not commit to the 20-week program and assessment requirements. The data collection took place at two sites (the Neurological Disorders, Ageing and Balance Clinic, Division of Physiotherapy, The University of Queensland and the Betty Byrne Henderson Centre for Women's Health Research at The Royal Brisbane and Women's Hospital).

Subjects were randomised via computer generated random numbers lists into either the exercising or control groups after their initial assessment. An independent researcher enrolled participants and assigned subjects to their respective groups. The ethics committee of the University of Queensland approved the study. All study participants gave written informed consent before participating.

Intervention

The exercise classes were run in two locations for participant's ease of access. One setting was a community church hall with parking facilities and the other was in a university physiotherapy clinic with good public transport options and parking. Subjects in the exercise group were offered a total of eight different times for their classes and consequently the group was broken into six smaller groups with a maximum of eight participants in each. It was hoped that allowing flexibility in time and place of class would assist the subjects to attend the sessions and schedule the exercise around other commitments. Subjects were not given any inducement, other than free attendance at classes. The subjects participated in a one-hour exercise class twice weekly for 20 weeks, with one break midway for the Christmas period. The exercisers were encouraged to continue the program at home over the two-week Christmas break, but no record was kept of this activity. The control subjects received no intervention or contact during this period.

Four physiotherapists instructed the classes and received 4 hours of training to ensure similarities across classes in terms of content, structure and progression. All were also given a video of an example of the intervention class. The classes included the following aspects: a warm-up and stretching period (8 minutes), a period of workstation exercise training (37 minutes), a period where exercises were done together as a group for interaction (10 minutes), and a cool-down, relaxation and stretching period (5 minutes). Many of the workstations were undertaken in close proximity to each other, with an emphasis on social interaction, discussion and enjoyment. Repetitions of the strengthening exercises were noted so that the program could be progressed by the individual in consultation with the physiotherapist. The exercise workstations were modified and developed from a specific balance strategy-training programme used in previous research aimed at reducing falls and improving balance in elders [14]. In this approach each exercise station is designed to focus on a specific task or activity that addresses aspects required for balance or strengthening including functional strength activities, flexibility, balance strategy practice, sensory integration, added attention demands during function, multi-task practice, trunk stability training and/or multi-directional skeletal loading. The main body of the classes consisted of 11 groups of exercise or activities (workstations) that could be individually progressed for differing levels of ability and to enable a progressive overload. The workstation approach enables promotion of self-efficacy where participants are encouraged to take control of their own exercise program by recalling each activity and how to increase the challenge at each station in order to progress difficulty, after training and consultation with the physiotherapist. Workstations offer different exercise foci that are multi-dimensional and adaptable for the participants' functional motor ability level and level of task challenge.

Measurements

The research physiotherapist who undertook all assessments was blinded to the group allocation of subjects. Self-reported demographic data collected at baseline included age, height, weight, hand and leg dominance, smoking history, education level, employment status, medical and surgical history, medications, including osteoporosis medication, falls history, caffeine intake, menstrual status and current activity levels [17].

Balance assessment

A total of five balance measures were undertaken (two laboratory and three clinical), each representing slightly different aspects of postural control. The two laboratory tests were taken utilising a Neurocom Balance Master ™, a dual force plate system, which incorporates a PC and software and estimates the centre of mass (COM) sway angle, based on height, assuming sway at the ankles. Three 10-second experimental trials were performed for each task of the tests and an average of the sway was recorded. The first test was the modified Clinical Test for Sensory Integration of Balance (mCTSIB), which measures amount of sway in four conditions: bilateral stance with eyes open and eyes closed whilst supported on both a firm and then a foam surface. The second test measured sway in unilateral stance with eyes open with both the left and right leg.

The clinical measures of balance included the timed 'up and go' test [18], functional step test [19] with left and right legs, and lateral reach test [20] with the left and right arms. The protocols described in the original reports of these clinical measurements were followed. In all tests three experimental trials were undertaken and the average was recorded.

Strength assessment

Hand-held dynamometry was used to assess maximal strength in the quadriceps, hip abductors, adductors, external rotators and thoracic extensors. In three experimental trials, the subject contracted against the dynamometer as strongly as possible and the peak force generated was recorded with an average of the three scores taken as the final measurement. The reliability and validity of hand-held dynamometry has been demonstrated in previous studies including the well-elderly and community-dwelling elderly fallers [21–24].

Bone density assessment

BMD was measured by dual-energy X-ray absorptiometry (DXA) with a GE Lunar Prodigy densitometer (GE Lunar, Madison, WI) using standard protocols. Statistically 68% of repeat scans fall within 1SD (+/− 0.012 g/cm^2 for AP spine L1–L4 and right and left femur total). The areas examined included the total lumbar spine (L1–L4), L1, L2, L3 and L4 and the total hip, femoral neck, trochanteric region, Ward's region and proximal femoral shaft on both left and right hips. The baseline measures were undertaken within the 6 months prior to initiating the study. The post-intervention assessments were completed within 4 weeks of the program ceasing.

Statistical methods

Results from previous RCT studies reported in the literature regarding the effect of training on balance, and strength were used to calculate sample size. When using balance and strength as outcome variables an alpha=0.05, expected standard deviation of 10% for change during intervention, a sample size of 78 was needed to achieve a power of 80%. These numbers would then allow for detection of a 5% treatment effect between groups. To accommodate for a possible 20% dropout rate [25–27] around 100 subjects were needed to be recruited.

The data were analysed on an intention to treat basis. Missing values from subjects lost to follow-up used baseline scores. Clinical trials usually do not collect sufficient data to allow good estimation, and the only commonly feasible options are using the last observed response (carry forward) or assuming that all missing responses were constant [28]. Comparisons of group characteristics and baseline scores were made using ANOVA. Descriptive statistics were used to show participant demographic profile. For the balance, strength and bone density measurements of intervention affect these calculations included means, standard deviations, with-in subject percentage change and net with-in subject percentage change (training effect). The with-in subject training effect (percentage differences between pre and post intervention measurements) was examined for group effect by ANOVA for balance and strength measurements. The effect of OP medication on training effect on BMD was determined by comparing responses to intervention between subjects taking OP medications and those not taking OP medications using ANOVA. All BMD responses from women were compared to controls for with-in subject training effect. The statistical package used was SPSS software version 11.0 for Windows (SPSS Inc., Chicago, IL).

Results

Recruitment and initial assessment was completed between July and September of 2003, re-assessment after the intervention period was completed between February and April 2004.

One hundred and ten women were assessed for trial eligibility. Ninety-eight women were randomised and underwent baseline assessment of balance, strength and bone mineral density —(one lady did not undergo hip BMD measurements due to bilateral hip replacements and therefore did not take part in the hip DXA analysis). Figure 1 shows a flow diagram of subject progression through the study.

The mean number of exercise classes attended was 28.2 (71%) with a range of attendance between 6 to 39 classes (15–98%), and 85.1% of subjects attended 20 or more classes (i.e., half of all classes).

Baseline data

The baseline demographic and clinical characteristics of each group are shown in Tables 1 and 2. There was a significant difference in osteoporosis medication usage between groups ($p<0.01$), eight women in the intervention group were taking OP medications. In order to determine

Fig. 1 Flow chart representation of subjects' progression through the study

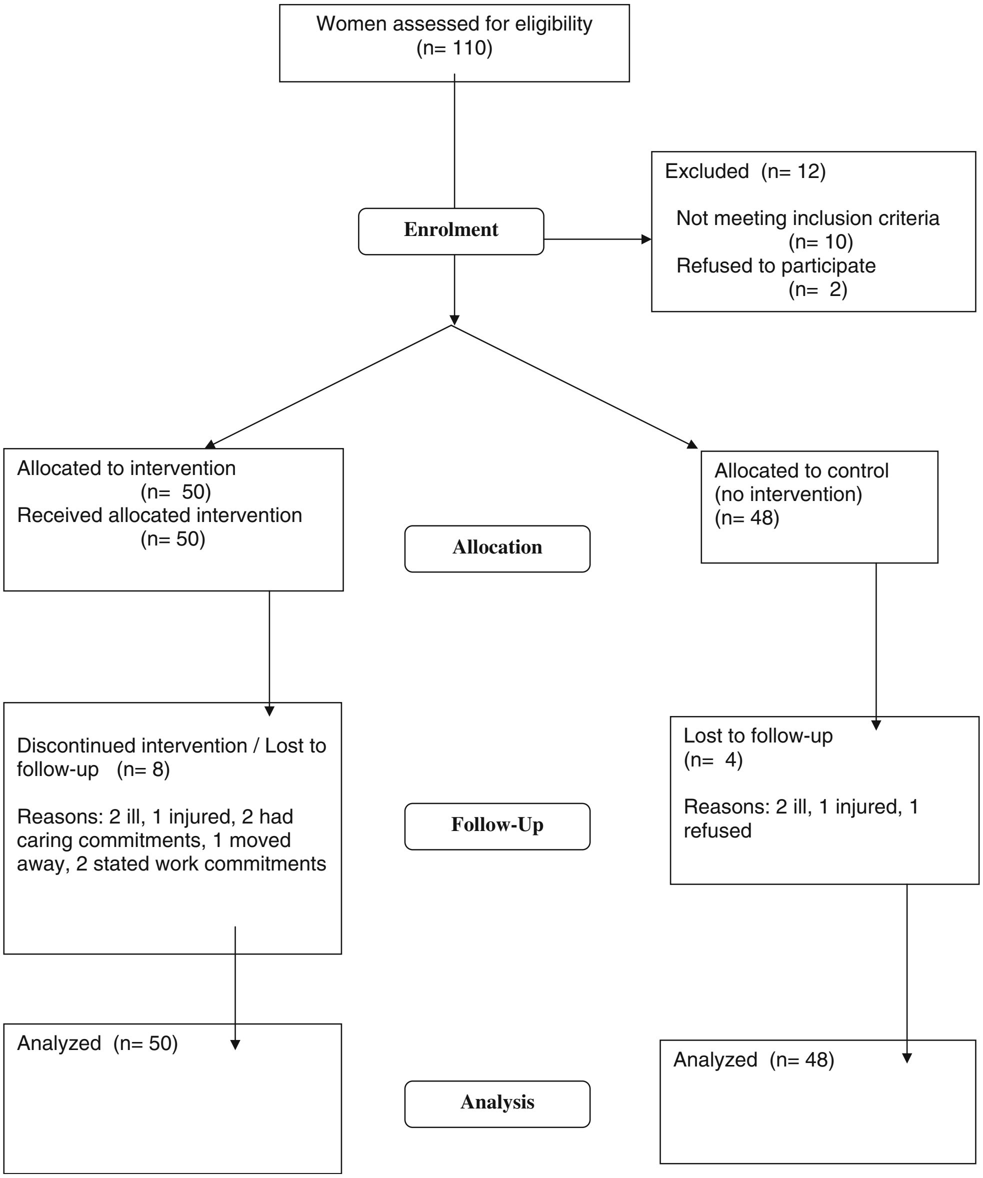

Table 1 Characteristics of the groups at baseline

Variable	Exercisers (n=50)	Controls (n=48)	P-value
Age (years)	61.5 (8.2)	61.9 (9.6)	0.89
Height (m)	163.2 (7.1)	162.5 (6.4)	0.37
Weight (kg)	67.6 (9.1)	71.4 (13.3)	0.24
Medical history (no. of conditions)	2.1 (1.5)	2.3 (1.9)	0.98
Surgical history (no. of operations)	2.7 (0.2)	2.7 (2.4)	0.95
Number of prescribed medications	1.7 (1.3)	2.4 (2.8)	0.52
Number of subjects taking osteoporosis medication	8 (0.4)	0 (0.7)	0.01
HRT (no. taking)	8 (0.3)	6 (0.4)	0.73
Ca supp. (no. taking)	12 (0.5)	7 (0.4)	0.28
Vit D supp. (no. taking)	4 (0.3)	2 (0.2)	0.62
Activity score*	3.2 (1.0)	3.3 (0.9)	0.72
Caffeine intake (no. cups/day)	3.2 (1.8)	3.7 (1.8)	0.17
Falls history (No. fallers in past 12 months)	15 (0.7)	10 (0.4)	0.29

Results are recorded by mean and standard deviation in brackets

*Based on a scale of 1 (very low) to 5 (very high), according to subjective assessment of professional, household and recreational activities [19]

Table 2 Categorised characteristics of the groups at baseline

Variable		Exercisers N=50	Controls N=48	P-value
Education level (level completed)	Year 10	15 (30)	17 (35)	0.96
	Year 12	7 (14)	2 (4)	
	Tertiary	28 (56)	29 (60)	
Hand dominance	right	47 (94)	45 (94)	
Leg dominance	right	47 (94)	46 (86)	
Employment	Retired	30 (60)	29 (60)	0.68
	Part-time	7 (14)	6 (12.5)	
	Full-time	13 (26)	13 (27)	
Menstrual status	Pre	3 (6)	4 (8)	0.49
	Peri	3 (6)	5 (10)	
	Post	44 (88)	39 (81)	
Smoking history	Never	36 (72)	40 (83)	0.25
	Ex-smoker	14 (28)	7 (15)	
	Smoker	0 (0)	0 (0)	
[a]Pack year history (ex-smokers)		2.77 (8.24)	1.05 (4.22)	0.20

All data are presented as number (%), except pack year history which is mean (SD) n=no. of “yes” cases in each group,% = percentage of “yes” cases within each group

[a] Pack year history = no” of years smoking × (no. of cigarettes a day / 20) e.g., 5 cigs per day for 10 years=2.5 pack year history (based on 20 cigs / pack)

Table 3 Mean values (sds) and within subject percentage change for the balance and strength measures at pre- and post- intervention assessments

	Exercisers (n = 50)			Controls (n = 48)			% Change difference** training effect	P-values
	Pre-test	Post-test	% change*	Pre-test	Post-test	% change*		
BALANCE								
Lateral reach left (cms)	16.09(3.66)	19.97(4.74)	27.37	15.67(4.49)	16.25(4.16)	8.49	18.88	.002[b]
Lateral reach right (cms)	16.87(3.20)	20.99(4.49)	28.44	16.60(3.97)	16.84(4.64)	3.64	24.8	.000[a]
Step test left (no. of steps)	16.84(3.28)	20.49(3.42)	24.3	16.96(3.44)	17.69(3.37)	5.02	19.28	.000[a]
Step test right (no. of steps)	16.98(3.41)	20.63(3.64)	24.66	17.48(3.72)	17.73(3.56)	2.11	22.55	.000[a]
Timed up and go (s)	6.76(1.18)	5.97(.84)	−10.37	6.92(1.44)	7.02(1.49)	1.82	12.19	.000[a]
Bilateral stance (deg/s sway)								
Eyes open	.23(.10)	.22(.08)	5.63	.19(.08)	.21(.08)	23.96	18.33	.076[T]
Eyes closed	.32(.15)	.29(.11)	−5.11	.27(.13)	.29(.14)	18.09	23.2	.011[c]
Foam eyes open	.72(.23)	.64(.19)	−9.39	.58(.21)	.62(.26)	10.99	20.38	.000[a]
Foam eyes closed	2.14(.89)	1.96(.69)	−3.04	2.26(1.19)	2.24(.98)	6.86	9.9	.112
Unilateral stance left (deg/s sway)								
Eyes open	1.89(2.51)	1.33(1.95)	−16.74	3.12(4.03)	2.84(3.53)	12.03	28.77	.018[c]
Unilateral stance right (deg/s sway)								
eyes open	1.93(2.25)	1.23(1.74)	−17.97	2.44(3.31)	2.52(3.44)	53.31	71.28	.013[c]
STRENGTH (KG)								
Hip abductors right	13.56(3.82)	15.26(4.09)	16.21	14.26(5.48)	14.03(4.38)	4.09	12.12	.001[a]
Hip abductors left	13.82(3.62)	15.47(3.68)	16.05	14.48(6.19)	13.58(4.34)	−2.05	18.1	.019[c]
Hip adductors right	11.73(3.39)	13.08(3.78)	16.49	12.37(4.66)	12.01(3.85)	.95	15.54	.013[c]
Hip adductors left	11.39(3.35)	12.88(3.77)	18.29	12.46(4.71)	12.27(4.59)	3.29	15.00	.013[c]
Hip external rotators right	7.93(2.89)	8.88(2.61)	18.78	9.68(2.96)	9.05(3.01)	−4.69	23.47	.037[c]
Hip external rotators left	8.08(2.98)	8.85(2.52)	15.85	9.40(2.99)	8.68(2.95)	−4.78	20.63	.080[T]
Trunk extensors	10.97(4.22)	10.89(3.82)	5.63	11.44(4.59)	9.11(3.44)	−14.98	20.61	.152
Quadriceps right	18.85(6.63)	20.52(6.07)	17.27	19.60(6.71)	19.88(7.39)	8.23	9.04	.003[b]
Quadriceps left	18.26(6.32)	19.97(6.23)	17.66	19.42(6.22)	19.78(7.13)	7.97	9.69	.004[b]

Increases in strength, distance reached and number of steps taken and decreases in sway or time indicate improvement

*Mean percentage change expressed as [(post-test score - pre-test score) / pre-test score] × 100

**Mean percentage change in exercise group minus mean percentage change in control group = net benefit of intervention or% difference between groups

[a] Significantly different from control group at $p<0.001$ [b] Significantly different from control group at $p<0.01$[c] Significantly different from control group at $p<0.05$ [T] Trend approaching significance ($p<.10$)

whether this variable impacted on results, subjects in the treatment group taking osteoporosis medications were compared to those not taking this medication. This revealed one site (L1, p=0.049) where BMD was measured to have a significantly better response to treatment.

Baseline - post-intervention comparisons

Pre and post scores and mean percentage changes in the test measures of balance, strength and bone density for the two groups are shown in Tables 3 and 4. At the completion of the trial the exercisers showed significant improvements in most balance and strength tests (see bolded results in Table 3).

A significant improvement in balance in the exercisers compared with controls was exhibited in nine of 11 measures. Those showing no change were bilateral stance eyes open and on foam with eyes closed (Fig. 2).

Strength improvements were noted in all muscle groups in the exercisers compared to the controls. Measures of hip abduction, adduction, right external rotation and quadriceps strength displayed significant gains in the exercise group though improvement in trunk extensors and left hip external rotators was non-significant (Fig. 3).

No significant difference was found between groups in BMD studies at the proximal femur or lumbar spine, irrespective of medication usage (Fig. 4). However, in 13 of the 15 sites in the hips and lumbar spine measured by DXA there was a non-significant trend towards improved bone density in the intervention group.

Adverse events

One subject complained of back pain during the exercise sessions and her program was modified to eliminate trunk extension moments in prone lying with total relief from any further discomfort.

Discussion

The study findings showed that this program of twice weekly weight-bearing exercise which incorporated specific balance strategy training stations and highlighted thoraco-lumbo-pelvic stability exercise was of sufficient duration, intensity and appropriateness to result in significant improvements in balance and muscle strength in community-dwelling women with osteopenia. Positive effects were also demonstrated at a non-significant level on bone density. However these positive results for bone changes could be spurious and may have arisen from the multiple comparisons completed, certainly small changes might be expected in the short time frame given. It is known from previous studies that clear results in bony changes would only be likely after intervention over a

Table 4 Mean values (sds) and within subject percentage change for the bmd measures at pre- and post- intervention assessments

	Exercisers (n=50)			Controls (n=48)			% Difference **between groups training effect	P- values
	Pre-test	Post-test	% change*	Pre-test	Post-test	% change*		
BMD (g/mm^2)								
Lumbar spine total	1.07(.20)	1.07(1.9)	−0.14	1.11(.16)	1.11(.16)	−0.84	0.70	.682
L1	1.00(.19)	.99(.19)	−0.49	1.04(.16)	1.03(.16)	−1.03	0.54	.915
L2	1.06(.21)	1.05(.20)	−0.33	1.10(.16)	1.10(.16)	−1.08	0.75	.723
L3	1.12(.21)	1.12(.21)	1.55	1.15(.16)	1.15(.16)	0.48	1.07	.890
L4	1.11(.23)	1.11(.23)	0.81	1.14(.18)	1.12(.19)	−1.34	2.15	.237
Total hip right	.91(.13)	.91(.13)	0.04	.94(.12)	.95(.12)	0.54	−0.50	.461
Femoral neck right	.86(.10)	.87(.10)	0.70	.91(.13)	.90(.13)	−0.97	1.67	.118
Ward's region right	.67(.14)	.68(.14)	0.74	.73(.14)	.72(.13)	−0.92	1.66	.308
Trochanter right	.75(.11)	.74(.11)	−0.49	.76(.11)	.78(.11)	1.39	−1.88	.063[T]
Femoral shaft right	1.08(.17)	1.09(.17)	0.42	1.13(.14)	1.14(.15)	0.26	0.16	.592
Total kip left	.91(.14)	.91(.14)	−0.04	.95(.13)	.95(.13)	−0.32	0.28	.946
Femoral neck left	.86(.10)	.86(.09)	−0.37	.90(.14)	.89(.14)	−1.40	1.03	.173
Ward's region left	.67(.14)	.68(.14)	0.55	.74(.15)	.72(.14)	−2.34	2.89	.136
Trochanter left	.75(.13)	.73(.12)	0.82	.77(.13)	.77(.14)	0.66	0.16	.685
Femoral shaft left	1.09(.18)	1.09(.18)	−0.43	1.14(.15)	1.13(.16)	−0.91	0.48	.369

*Mean percentage change expressed as [(post-test score - pre-test score) / pre-test score] × 100

**Mean percentage change in exercise group minus mean percentage change in control group = net benefit of intervention or% difference between groups

[a] Significantly different from control group at $p<0.05$

[T] Trend approaching significance ($p<.10$)

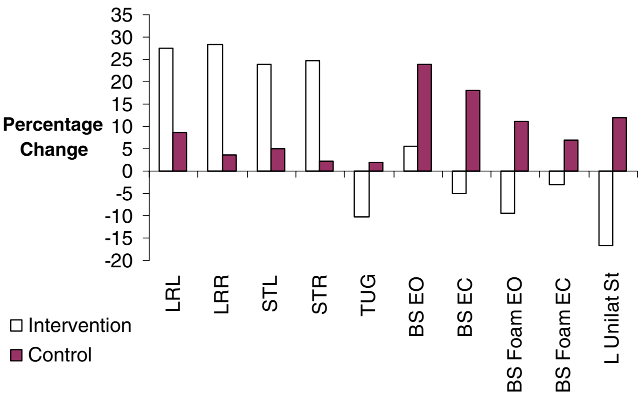

Fig. 2 Training effect on balance measures

longer period and DXA analysis at least eight months apart to account for bone metabolism and the remodelling cycle [11, 13].

The intervention group included eight women taking medication for the management of osteoporosis. The intervention effect was compared between women taking bone medication with those not taking this medication. This analysis found only one site where there was a significantly different response (L1). This comparison suggests that within the study bone medication has not strongly affected the subjects' response to exercise.

A review of the recent literature identifies a range of BMD changes or treatment effects after various interventions. In this study there are varied responses in both the lumbar spine and hip. We found non-significant deterioration in total lumbar spine (L1–L4) measurements (exercisers - 0.14% and controls - .84%). Notably, in all levels of the lumbar spine there was a positive training effect although non-significant. No significant changes in total hip scores were shown, although again there was a pattern of positive training effect, particularly in the left hip, which may suggest a slowing of bone loss amongst exercisers.

These findings are not dissimilar to previous reports. Of the 53 treatment effects reviewed in one meta-analysis 42 were positive (18 significantly) and 11 negative (one significantly). The range of BMD treatment effects was large, between −6.6% and 10.2% [29].

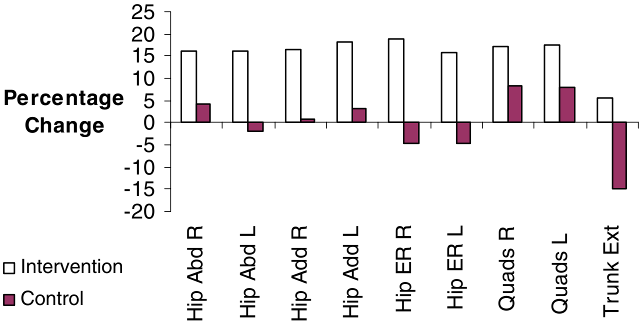

Fig. 3 Training effect on strength measures

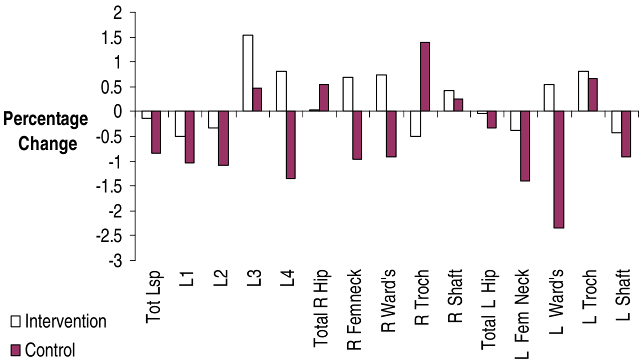

Fig. 4 Training effect on BMD measures

Results from the trial assessing BMD changes in 132 postmenopausal women with programmed Tai Chi Chun exercise (45 minutes per day, five days per week for 12 months) displayed a slowed rate of loss of BMD in the exercisers (2.6- to 3.6-fold retardation of loss in the distal tibia.) [12]. Like this study, the one reported here examines a lower impact form of exercise that is often appropriate for older people and/or those with degenerative joint changes who have increased chance of injury. When the results of our study are compared to these and other interventions reported in one systematic review that focused only on BMD, the main difference apart from exercise method and content is duration of intervention (20 weeks compared to 40 or more weeks)[10]. Frequency of intervention was variable for these studies of longer duration and this too can alter beneficial effects by changing overall exercise intensity.

In previous studies there have been limited data given on BMD sites measured and recorded [11]. Many studies concentrate on spine density and most record only total hip scores from one side only. It may be important to study hip measurements bilaterally and at multiple sites to more accurately assess where changes are occurring after given interventions. This may then inform researchers more about where certain exercise programs are affecting bone mineral density and give further information to enable best practice exercise prescription.

The improvements in balance induced by the program complements the findings of previous studies that have employed regimens of balance and workstation training [14, 30]. This is also consistent with other studies that have employed agility training with similar rationale and activities to those incorporated in this study, and found improved postural stability in other populations of older people [15, 30, 31].

The improvements in isometric muscle strength also concur with other studies that have achieved this through weight-bearing activities. Indeed the percentage improvements are as good as some studies' results that have utilised the addition of external weights and resistances in the form of high-intensity progressive resistance training [13]. We theorise that balance training including weight-bearing exercises alone may be a more appropriate and safe form of achieving strength gains with minimal risk of injury or falls to participants also, especially important in the older age groups [15]. This concurs with reviewers' conclusions after analysing studies on progressive resistance training in older people that identified the difficulty in determining the degree of risk and benefit of this form of training with adverse events generally poorly collected and recorded [32].

A limitation of the study in regards to strength assessment is the use of a hand-held dynamometer. Reliability is dependent on the strength of the tester and their ability to maintain the testing position while holding against the resistance of the subject. For subjects able to produce high forces, an examiner may not be able to resist these forces, thus a maximum isometric strength may not be recorded and variability may be increased. The use of a stationary dynamometer that is attached to a strong fixed instrument would lead to increased precision as documented previously [33].

Compared with other studies our dropout rate of 12% was low and the attendance at sessions was reasonable (71%) especially considering the hot summer experienced and the age group [10, 12]. Attendance and adherence is clearly an important factor that influences the effectiveness of exercise therapy. Attendance rates in previous studies range from 48% to 87% with adherence rates from 65% to 82% [11]. Exercise adherence must be addressed if programs such as this are to be helpful to the majority. Although we acknowledge the need to formulate a self-managed program suitable to a larger spectrum of the population it is not without realising there were factors in this physiotherapist-led program that would have positively effected compliance including qualified instructors, convenient locations, and group participation.

The findings of this research support stances towards the management of osteoporosis that include multi-disciplinary approaches to treatment not only involving the need for medication and radiological review [34]. The prescription of appropriate balance and exercise training programs is an important part of effectively managing women with osteopenia and assisting in the prevention of osteoporosis and fractures. Clearly further studies are required to answer many questions related to different forms and amounts of exercise prescription, different risk factors, rationales and programs suitable to young persons, aging adults and older populations.

Further research with this form of training is necessary to examine whether the program has similar benefits when undertaken as a self-monitored home-based program with an instructional exercise video. Future research to evaluate changes in measurements with the program administered over a longer duration (>12 months) is warranted. Ultimately it would be of great impact to assess actual fracture data through long-term study; the difficulties with achieving this have been noted by others in meta-analyses [4, 10, 11, 13].

The prevention of osteoporosis and falls is vitally important for ageing women, as the consequences of fractures and injury are high. The exercises used here are relatively easy to implement in the community and were shown to positively affect measures that are directly associated with fracture risk in osteopenic women. Women should be encouraged to begin preventative type exercises and empowered through education early in the lifespan. Women's health and risk status may be improved by focusing on exercise prescription that targets both bone health (via weight-bearing exercise and stability training) and falls prevention (via workstation balance and strength training).

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