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A randomised controlled trial of Tai Chi and resistance exercise on bone health, muscle strength and balance in community-living elderly people

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Abstract

Background: the beneficial role of exercise in improving bone mineral density, muscle strength and balance, has been documented predominantly in younger populations. These findings may not apply to elderly populations with limited ability to perform exercises of high intensity.
Objective: to examine the effects of Tai Chi (TC) and resistance exercise (RTE) on bone mineral density (BMD), muscle strength, balance and flexibility in community living elderly people.
Design: randomised controlled trial, using blocked randomization with stratification by sex.
Setting: a community in the New Territories Region of Hong Kong, China.
Subjects: one hundred eighty subjects (90 men, 90 women) aged 65–74, were recruited through advertisements in community centres.
Methods: subjects were assigned to participate in TC, RTE three times a week, or no intervention (C) for 12 months. Measurements were carried out at baseline, 6 and 12 months. Analyses of covariance (ANCOVA) adjusted for age, and baseline values of variables that were significantly different between groups: i.e. smoking and flexibility for men; quadriceps strength for women.
Results: compliance was high (TC 81%, RTE 76%). In women, both TC and RTE groups had less BMD loss at total hip compared with controls. No effect was observed in men. No difference in either balance, flexibility or the number of falls was observed between either intervention or controls after 12 months.
Conclusion: the beneficial effects of TC or RTE on musculoskeletal health are modest and may not translate into better clinical outcomes.

Keywords: *Tai Chi, resistance exercise, bone mineral density, muscle strength, balance, elderly*

Introduction

Osteoporosis is occurring as an epidemic in the urbanised parts of Asia. For instance, in Hong Kong, 3 per 1,000 elderly men and women fracture their hip every year [1]. A lack of physical activity and poor muscle strength were found to be important risk factors for hip fracture among the elderly [2, 3]. Studies in Caucasian populations showed weight-bearing exercises to be effective in maintaining bone mineral density (BMD) [4], and mixed type exercises for preventing falls [5]. The impact of exercise on falls is likely to be mediated by improvement in leg muscle function

[6, 7], faster neuromuscular reactions in leg muscles resulting in more efficient protection in postural disturbances [8], balance, particularly for exercises such as Tai Chi (TC) [9, 10], and fear of falling [10, 11]. Therefore, exercise is an important intervention in the maintenance of bone health, muscle strength and balance, thereby reducing the risk of falls and fractures. In elderly people, exercises of a strenuous or intense nature with documented evidence of health benefits may not be feasible. It has been suggested that TC is a suitable form of exercise in balance and leg strength training [10], while resistance exercise (RTE) is considered a key intervention in counteracting sarcopenia associated with ageing [12]. The majority of previous studies on TC have examined the effect on falls, with conflicting results [9, 13–17]. It is possible that less marked effects are observed with increasing frailty [14, 15]. Few studies examined the effect of TC on BMD. Since TC is a weight-bearing exercise, a beneficial effect may be expected, and this is observed in postmenopausal women between 50 and 60 years of age [18–20]. However, the effect in elderly people is uncertain. Therefore, we conducted a randomised controlled trial comparing the effects of TC and RTE in community-living elderly people, to determine whether these are suitable exercise interventions for improving BMD, strength, balance and flexibility in terms of effectiveness and compliance.

Subjects and methods

The study has been approved by the Clinical Research Ethnics Committee of the university, which operates according to the principles of the Declaration of Helsinki.

Subjects

One hundred and eighty subjects (90 men and 90 women aged 65–74 years) were recruited through notices posted in four community centers in the region of Shatin, Hong Kong. Subjects who could not walk 8 metres without assistance, who had neurological disease which impaired mobility, cardiovascular disease which result in shortness of breath or angina on walking up one flight of stairs, a diagnosis of dementia, and those who were already performing TC or RTE or other exercises regularly were not recruited.

Subjects were then randomised into three study groups by computer-generated blocked randomisation, with stratification by sex, and using block sizes of three. Block randomisation was undertaken in order to achieve equal sample sizes within each treatment group during the study period. In our study, neither the staff responsible for recruitment or interviews nor those responsible for measurement were informed about the subjects' treatment assignment or that treatment allocation was by block randomisation. Only the project director (PD) and the staff person responsible for scheduling the subjects for TC and RTE have access to the list linking the subjects' names to their treatment assignments, and these individuals were not involved in any of the data collection. Subjects were also not scheduled for outcome measurement according to their order of recruitment or order of treatment allocation. With these procedures, treatment allocation is safely concealed from staff responsible for data collection. A baseline questionnaire was administered to measure dietary calcium intake, physical activity, cigarette smoking and alcohol consumption.

Intervention

The three groups of study subjects were assigned to participate in TC or RTE. No exercise was prescribed to the control group.

The TC group performed TC three times per week, using the Yang style with 24 forms. The RTE group also performed exercise three times per week. A theraband of medium strength (Hygenic Cooperation, Akron, OH, USA) was used, and each of the following motions was repeated 30 times: arm lifting, hip abduction, heel raise, hip flexion, hip extension, squatting ankle dorsiflexion.

Measurements

Bone mineral density

BMD was measured by dual X ray densitometry (Hologic QDR 4500) at the total hip and spine at baseline, 6 months and 12 months. The coefficient of variation for BMD measurement in our laboratory was less than 1% at both the total hip and spine.

Muscle strength

Grip strength was measured using a handgrip dynamometer Grip D (Takei Scientific Instruments, Tokyo, Japan). Subjects were asked to hold the instrument in one hand. The knob was then turned to adjust the grip range until the second joint of the subject's forefinger was bent through 90 degrees. Subjects were then asked to stand up straight and relax. They were told to extend their arms downward, holding the Grip D comfortably with one hand. Subjects then gripped the instrument with maximum force, without letting their arms touch their body. Grip strength was measured on the dominant hand, to the nearest 0.5 kg. Measurements were repeated three times on the dominant hand and the average values were used.

A quadriceps device (Isometric Dynamometer Baseline, Genova, Italy) was used to measure the strength of the quadriceps femoris (vastus medialis, vastus lateralis, vastus intermedius, and rectus femoris) muscles. Subjects were asked to sit with their lower legs at right angles to their thighs and the front of their ankles against the quadriceps device. They were then asked to extend the knee without placing their hands on a table. Three measurements were made with each leg alternately.

Balance and coordination

A SMART Balance Master (NeuroCom International Inc., OR, USA) was used to measure balance. The ability of subjects to utilise somatosensory, vision and vestibular inputs

Table 1. Characteristics of subjects in the study

	Men (mean ± SD/ %)				Women (mean ± SD/ %)			
Characteristics	TC group ($N = 30$)	Resistance training group ($N = 30$)	Control ($N = 30$)	P-value[a]	TC group ($N = 30$)	Resistance training group ($N = 30$)	Control ($N = 30$)	P-value[a]
Mean age (years)	68.2 ± 2.4	68.67 ± 3.0	68.07 ± 2.7	0.67	69.67 ± 2.8	69.57 ± 3.2	69.27 ± 3.0	0.87
(%) of cigarette smokers (N)				0.01				0.31
Never	27 (8)	20 (6)	60 (18)		87 (26)	100 (30)	93 (28)	
Ex-smokers	53 (16)	57 (17)	17 (5)		3 (1)	0 (0)	3 (1)	
Current smokers	20 (6)	23 (7)	23 (7)		10 (3)	0 (0)	3 (1)	
(%) of alcohol drinkers (N)				0.33				0.24
Never	37 (11)	27 (8)	50 (15)		87 (26)	83 (25)	83 (25)	
Past drinkers	23 (7)	17 (5)	17 (5)		10 (3)	7 (2)	0 (0)	
Current drinkers	40 (12)	57 (17)	33 (10)		3 (1)	10 (3)	17 (5)	
Physical activity (hours per week)	3.17 ± 3.5	4.14 ± 4.5	3.81 ± 9.4	0.67	5.83 ± 4.0	6.83 ± 4.7	6.67 ± 3.7	0.67
Body mass index (kg/m^2)	23.56 ± 3.4	24.10 ± 3.4	23.89 ± 3.1	0.82	24.40 ± 4.3	24.60 ± 4.0	24.93 ± 3.0	0.86
Body mineral density (g/cm^2)								
Total hip	0.86 ± 0.11	0.89 ± 0.09	0.85 ± 0.12	0.35	0.67 ± 0.09	0.68 ± 0.11	0.70 ± 0.10	0.64
Femoral neck	0.69 ± 0.11	0.73 ± 0.08	0.68 ± 0.10	0.16	0.57 ± 0.07	0.57 ± 0.09	0.59 ± 0.08	0.53
Intertrocharteric area	1.04 ± 0.13	1.06 ± 0.12	1.01 ± 0.14	0.26	0.83 ± 0.12	0.82 ± 0.14	0.85 ± 0.12	0.69
Total spine	0.95 ± 0.16	0.99 ± 0.16	0.96 ± 0.15	0.59	0.68 ± 0.09	0.69 ± 0.12	0.75 ± 0.09	0.04
Muscle strength								
Grip strength (dominant) (kg)	14.16 ± 2.1	14.83 ± 3.3	14.14 ± 1.9	0.48	9.27 ± 1.8	9.52 ± 2.0	9.70 ± 1.5	0.64
Quadricep (average) (kg)	21.73 ± 4.5	23.29 ± 3.0	22.04 ± 4.0	0.26	14.22 ± 5.3	18.64 ± 5.2	16.54 ± 4.7	0.004
Balance (score) (1–100)	73 ± 6	74 ± 5	71 ± 7	0.21	72 ± 7	69 ± 7	69 ± 7	0.24
Flexibility (cm)	13.20 ± 8.2	7.40 ± 9.9	12.27 ± 8.0	0.03	5.03 ± 9.0	2.57 ± 11.5	3.37 ± 9.0	0.62

[a] P-value of ANOVA for continuous or Chi-square for categorical variables where appropriate.

to coordinate sensory systems in an unstable support surface condition was tested. Anterior-posterior displacement of the body centre of gravity in static mode was applied.

Values representing actual scores in each trial were used. Six trials were tested: align eyes open, align eyes closed, swayed vision, swayed support, eyes closed and swayed support, and swayed vision and support. The specific movement strategy (ankle or hip) used to maintain balance was recorded. The vertical axis represented 'stability' (absence of sway), where '100' was most stable and '0' (fall) was least stable.

Stance time

Two trials each of semi-tandem, tandem and single stance were performed with subjects barefoot and with arms crossed. Two trials were performed and the result of the trial with the longer duration was used [21].

Gait velocity

Gait velocity was measured over an 8-metre course, at the usual walking pace, without external help. The time was measured in seconds, using a stopwatch.

Bend reach performance test

Bend reach was measured by recording the lowest point that a subject's hand could reach above or below the ground by bending the body forward, with extension at the knee joint.

Subjects were asked to stand on the bend reach measuring board (a fixed ruler) with their legs held together. They were asked to bend downwards, and the lowest height reached by the fingers from ground level without bending the knee was recorded. This was measured to the nearest centimetre. The best score of two trials was used as the test score.

Power calculations

Due to lack of data in the older age group, the number of subjects was determined based on previous randomised controlled trials of the effects of TC on bone loss and quadriceps strength [19, 20] in postmenopausal women. Based on these studies, to demonstrate a between-group difference of 6% in spine and femoral neck BMD with a power of 80%, and a significance level of 95%, 60 and 39 subjects are required, respectively, for each group. However, it is uncertain whether a 6% difference in BMD is clinically meaningful in terms of fracture reduction [19]. For quadriceps strength, to detect an increase of ± 5 kg with a power of 80% and significance level of 95%, 60 subjects are required in each group. Again, it is uncertain whether an increase of this magnitude is clinically significant in translating to a reduction in falls. No estimation was carried out for the other measures.

Statistical methods

All of the statistical analyses were performed using the Statistical Package for the Social Sciences for Windows, Standard version 11.0 (SPSS Inc., Chicago, USA, 2001 Microsoft Corporation). According to the protocol pre-specifying subgroup analysis, results for men and women were carried out separately.

Analysis of variance and chi-square tests were used to compare continuous and categorical baseline measurements. The percentage changes in BMD or absolute changes in measurement units for muscle strength, balance and flexibility were calculated, and the difference between groups were compared using analysis of covariance (ANCOVA) adjusted for age, and baseline values of variables that were significantly different between groups, i.e. smoking and flexibility for men; quadriceps strength and spine BMD for women.

Results

A total of 180 subjects (90 men and 90 women aged 65–74 years) were recruited. Two men and two women dropped out prior to the 6-month follow up and data for these four subjects were not included in the final data analysis (please see the figure in Appendix 1 in the supplementary data on the journal website http://www.ageing.oxfordjournals.org/).

The baseline characteristics of subjects are shown in Table 1. There were no significant differences in dietary calcium intake, physical activity, alcohol consumption, body weight and BMD, between the three intervention groups. However, among men, there were more smokers in the control group, and a significant difference in flexibility between RTE and control; while among women, quadriceps strength was significantly different between the three groups.

The compliance with exercise was high; with the mean attendance rate at 81% for the TC group and at 76.3% for the RTE group, with no attrition between 6 and 12 months. The 12-month percentage changes in BMD are shown in Table 2. In men, there was no difference in percentage change in BMD between the three treatment groups. However, in women, both exercise groups had significantly less BMD loss at the total hip than the control group. Although the *P*-value was <0.05 for the ANCOVA for BMD at the spine, the comparison between each intervention and control group did not reach statistical significance.

No significant change in muscle strength balance or flexibility was observed in men and women for either exercise group compared with controls (please see Appendix 2 and 3 in the supplementary data on the journal website http://www.ageing.oxfordjournals.org/). There was no statistically significant difference on the numbers of falls between the groups during the study period (TC group: 15/60; RTE group: 24/60; Control group: 31/60).

Discussion

Both TC and RTE have been demonstrated to have beneficial effects on musculoskeletal health in previous studies. The

Table 2. Percentage change of bone mineral density at the hip and spine among the three intervention groups at 12 months

	TC group mean ± SE	RTE group mean ± SE	Control group mean ± SE	*P*-value
Men ($N = 88$)	($N = 30$)	($N = 29$)	($N = 29$)	
Total hip	−0.48 ± 0.37	−1.20 ± 0.38	−0.15 ± 0.38	0.16[a]
Total spine	1.35 ± 0.40	1.27 ± 0.42	0.54 ± 0.42	0.35[a]
Women ($N = 88$)	($N = 28$)	($N = 30$)	($N = 30$)	
Total hip	0.07 ± 0.64[c]	0.09 ± 0.62[c]	−2.25 ± 0.60	0.01[b]
Total spine	0.10 ± 0.50	1.98 ± 0.48	0.98 ± 0.47	0.04[b]

[a] *P*-value of ANCOVA adjusted for age, smoking status and flexibility at baseline.
[b] *P*-value of ANCOVA adjusted for age, quadriceps strength, and spine BMD at baseline.
[c] *P*-value < 0.05 comparing TC or RTE group with control group.

majority of studies on the effect of TC have concentrated on muscle strength, balance and falls reduction [9–11]. However, recent meta-analysis of randomised controlled trials were inconclusive [14, 17] regarding effectiveness in falls prevention among elderly people. No previous randomised controlled trial of the effect of TC on BMD in the elderly had been reported, although beneficial effects have been observed in postmenopausal women [18–20]. This study showed no benefit to men with regard to BMD, but a modest effect was observed in retarding bone loss at the hip in elderly women. It is possible that the intensity of TC as an exercise for men is insufficient, while for women who are likely to be physically more frail, TC as an exercise is sufficient in intensity to produce a beneficial effect on BMD. Contrary to previous studies mainly in younger populations, TC did not result in any significant improvement in muscle strength, balance or flexibility since all the above parameters decline with age. It is possible that the beneficial effects of TC are only present when above a certain threshold of physical functionality.

RTEs, by increasing mechanical load on the skeleton, may be expected to have beneficial effects on BMD. Again, few studies examined this aspect specifically in the elderly population. Previous studies have been carried out in menopausal women [22–24] showing increased BMD with RTEs. As for TC, a beneficial effect was observed in women only, and the magnitude of the effect is similar to that for TC. Contrary to previous studies on RTEs [6, 7, 25–27], we did not demonstrate any improvements in muscle strength and balance. It is possible that for this cohort, the tolerated intensity of exercise was not sufficiently high to provide observable improvements in strength, balance and flexibility.

To achieve health benefits from exercise programmes, it is essential to construct the content such that the elderly population find it feasible and enjoyable, and for the programmes to be carried out in community centres that have other health promotion or health service functions, such that the programme may become incorporated as part of their regular activities. The location in a community health care setting would have an indirect benefit of reinforcing the goals of exercise programmes in achieving specific health benefits. The programmes can also be incorporated with social programmes, and be regarded as a form of social support. In view of the age-related decline in many physical functions, it could be that when in advanced age, the most important benefit of exercise programmes will be in the area of promoting social support and social interaction, which are key components to positive ageing [28]. In this regard, the main criteria for choice of exercise could be that it is enjoyable, containing different components targeted towards improving aerobic capacity, balance and muscle strength, with a key goal of motivating large numbers of elderly people living in the community to participate on a regular basis. For example, golf may be an equally beneficial exercise. A previous study comparing golfers and TC practitioners noted that both groups have better knee joint proprioceptive acuity compared with age matched controls, and comparable to younger subjects [29].

There are some limitations in this study. We have excluded subjects with some chronic diseases, and it could be argued that health benefits could be more marked in such subjects. Thus, a meta-analysis showed that secondary prevention programs with or without a structured exercise component improve health outcomes in patients with coronary disease [30]. Secondly, we could not exclude 'contamination' of the control group, since they attended a health centre for evaluation, and the centre had many health promotional material on display. During the study period, the government also mounted a healthy ageing campaign promoting exercise, among other messages. Control subjects may have altered their lifestyle accordingly. Thirdly, we were unable to do formal power calculations for outcome measures. It is possible that significant differences were not detected due to inadequate sample size (since a *post hoc* power calculation showed values of approximately 70%), and especially since many variables were being compared. The strengths of this study lie in the randomised control trial design, the long duration of 12 months, and the high compliance. We may conclude that while both TC and RTE may suitably be incorporated into regular community exercise programmes, both exercises having good compliance, the health benefits were not very marked, there being some marginal benefit in terms of retarding bone loss in

women after 12 months. Results from previous studies of younger populations may not be extrapolated to elderly populations.

Supplementary Data

Appendix 1, 2 and 3 are available to online subscribers at http://ageing.oxfordjournals.org.

Key points

- Beneficial effects of Tai Chi and resistance exercise on bone mineral density, muscle strength and balance, documented in younger populations may not be applicable to older populations.
- With increasing age and inevitable decline in physical function, ability to do exercise at a sufficient intensity for health benefits may be limited.
- Both Tai Chi and resistance exercise can be incorporated into regular community centre activities, with good compliance.
- Apart from a reduction in the decline in bone mineral density at the hip in women, there was no effect on BMD in the spine, quadriceps strength, balance, flexibility or number of falls.

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Conflicts

None of the authors have any declaration of conflict of interest with respect to any products used in the study or referred to in this article.

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National audit of continence care for older people: management of faecal incontinence

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Abstract

Introduction: faecal incontinence in older people is associated with considerable morbidity but is amenable to successful management. Quality standards in this area were previously subject to a pilot audit in primary, secondary care and care homes to allow providers to compare the care delivered by their service to others and to monitor the development of integrated continence services as set out in the National Service Framework for Older People. This study reports the results of the national audit.

Results: data were returned by 141 primary care sites, 159 secondary care trusts (involving 198 hospitals) and 29 care homes. Data on the care of 3,059 patients/residents with bowel problems were analysed. Fifty-eight per cent of Primary Care Trusts (PCTs), 48% of hospitals and 74% of care homes reported that integrated continence services existed in their areas. Whilst basic provision of care appeared to be in place, the audit identified deficiencies in the organisation of services and in the assessment and management of faecal incontinence.

Conclusion: the results of this audit indicate that the requirement for integrated continence services contained within the National Service Framework for Older People has not yet been met. Basic assessment and care by the professionals directly looking after older persons is often lacking. There is an urgent need to re-establish the fundamentals of continence care into the daily practice of medical and nursing staff, and undoubtedly, action needs to be taken with regard to the establishment of truly integrated, quality services in this neglected area of practice.

Keywords: *faecal incontinence, older people, audit, clinical effectiveness, elderly*