中文計畫名稱：阻力運動訓練對停經後骨質疏鬆婦女的效果

英文計畫名稱：Effect of Resistance Training in Osteopenic Postmenopausal Women

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一、摘要(Abstract)

中文

本研究的目的在探討 24 週軀幹肌和姿勢肌之運動訓練對停經後骨質不足婦女的效果。二十八名經 DEXA 確切合乎受試者標準的婦女參與且完成本研究，14 名患者志願接受每週二次每次約 30-40 分鐘的運動訓練，訓練項目主要為軀幹肌和姿勢肌的訓練，另 14 名患者則不接受此等運動訓練是為對照組。所有的受試者在研究期間均不得改變其藥物、飲食或生活型態，並在 24 週的前、後接受軀幹肌和膝伸肌之肌力與耐力、一分鐘仰臥起坐和伏地挺身、身體組成、最大攝氧量以及三處骨密度（L2-4、股骨頸和遠端股骨）的測量。結果顯示兩組間在 L2-4 骨密度(6.3 vs 1.9%)、膝伸肌肌力、軀屈肌耐力有明顯的差異($p<0.05$)。**關鍵詞**：軀幹肌肉運動和姿勢訓練、骨密度、停經後骨質不足婦女

英文

Osteoporosis is one of the most common skeletal disorders affecting postmenopausal women. The purpose of this study was to investigate whether an exercise program designed mainly to the trunk and postural muscles was beneficial for bone mineral density (BMD) in osteopenic postmenopausal women. Osteopenia was defined to be more than one standard deviation below the mean BMD of premenopausal women in this study.Twenty-eight postmenopausal women participated in this study, 14 in exercise group and 14 served as controls. The BMD of the spine (L2 to L4), right femoral neck, and distal femoral condyles of each woman was examined by dual X-ray absorptiometry. In addition, measurements of number of sit-ups and push-ups in one minute, strength and endurance of knee extensors and trunk muscles, body composition, and maximal oxygen consumption were taken. The exercise program was instructed to all subjects that took 20- 30 minutes long per session three times per week for 24 weeks, once a week being supervised by physical therapist in hospital. The results showed that in the exercise group had significant improvements in BMD of L2-4, number of sit-ups and push-ups in one minute, strength and knee extensors, and maximal oxygen consumption after 24 weeks, while decreases in strength of knee extensors and endurance of trunk flexors. The between-group comparisons showed significant improvements in BMD of L2-4, strength of knee extensors, trunk flexor endurance, and number of sit-ups over those of the control group. In conclusion, minimally supervised trunk and postural muscle exercises was able to improve BMD of L2-4, and strength of knee extensors and trunk flexors. **Key words: Trunk and postural muscle exercises - Osteopenia- Postmenopausal women.**

二、緣由與目的

Osteopenia and osteoporosis are now recognized as a major public health problem in postmenopausal women. Knowledge of disabling osteoporotic fractures has motivated research in interventions to prevent or slow down the progression of the disease [1]. Physical activity and back muscle strength were reported to correlate with BMD of vertebral bodies [2,3]. Researchers have attempted to improve BMD of spine by exercising trunk muscles. Most of studies demonstrated increased strength, but conflicting results of beneficial effects on BMD [4-7]. Asides of problems of research metholody, difficulties in conducting and controlling compliance in long-term exercise programs were part of the reasons. Previous studies have used general weight-bearing activities as the main form of exercise intervention [8-10], however, an optimal exercise regimen has not been identified. Therefore, the purpose of this study was to investigate whether a 24-week minimally supervised exercise program, mainly on trunk and postural muscles would be beneficial for postmenopausal women with osteopenia.

三、方法

Subjects

Twenty-eight postmenopausal at least 6 months women were recruited from the City of Taipei through various advertising strategies. All subjects took a dual-energy X-ray absorptiometric evaluation (Norland XR-26 Mark II machine, Norland Corp., WI) and were judged to be osteopenic if either of the BMD value of the L2-4 spine or femoral neck were more than 1 standard deviation below the mean of premenopausal women.

After signing the written consent, each participant was interviewed to obtain her past medical history and current medications. Any participant with medical conditions which might interfere with the result of the test, such as hyperparathyroidism, renal disease, poorly controlled hypertension and cardiopulmonary disease, or has taken medicines that could interfere with calcium absorption was excluded from this study.

Totally fourteen subjects completed 24-week exercise training and 14 subjects in the control group who did not receive any new form of treatment during this period but a re-evaluation afterwards. They were all asked not to change their physical activity habits or diet until completion of the study that were evaluated every 8 weeks through chart review and questionnaire inquiry.

Measurements

BMD at 3 sites, strength and endurance of trunk muscles and right knee extensors, numbers of sit-ups and push-ups in one minute, body composition, and maximal oxygen consumption were measured before and after the 24-week interval. Physical activity and calcium intake were assessed every two months for controlling the confounding variables.

A Cybex 6000 (Cybex, Division of Lumex Inc., Ronkonkoma, NY) was used to measure the isometric strength and dynamic endurance of the trunk muscles at 0° and right knee extensors at 90° of knee flexion. Each contraction lasted for five seconds, and there was a resting period of at least 15 seconds between trials. The endurance test for knee extensors consisted of 25 cycles of reciprocal movements at the speed of 180°/sec. While the endurance test for trunk muscles consisted of 15 cycles of reciprocal flexion/extension contractions within 80° range of motion at 120°/sec. The muscular endurance was evaluated by the percentage of torque decline which was calculated from the differences between the mean generated torque of the first and last five contractions divided by the mean torque of the first five contraction.

Subjects were encouraged to produce their best efforts of performing curl-up and push-up exercises to failure in one minute. The push-up test is administered with the individual in the modified "up" position. Participants lowered themselves down until the chest touches the floor, and then raising back to the up position. In the curl-up test, the subjects started by lying on their back with knee bent, hands should be keeping beside the trunk. When they curled up, hands should be moved 3 inches apart from the initial position.

Body composition was measured using a bioelectrical impedance analysis method (RJL Systems, Detroit, MI.). Fat-free mass (FFM) was expressed in kilograms, and body fat as percentage of body weight.

Each subject performed a maximum exercise test with continuous ECG monitoring following an initial practice session on the cycle ergometer. The criteria for termination included at least two of the following conditions: volitional fatigue, heart rate at or near 90% of the age-predicted maximum, or the respiratory exchange ratio >1.10. The graded exercise protocol consisted of 1-minute stages starting at 10 watts with 10 watts increment at each successive stage while maintaining a pedaling rate of 50 to 60 rpm. A metabolic measurement system (Vmax29 Metabolic Measurement System, SensorMedics, Anaheim. CA) was used to sample the expired air breath by breath. VO_2max presented as l/min and ml/kg/min were used for data analysis.

Physical activity was evaluated with an interviewer-administered physical activity questionnaire to assess a 7-day caloric expenditure during the previous week. Calcium intake was assessed by a three-day food frequency questionnaire and was expressed as milligrams per day. Details of both were described in our previous study.

Exercise Program

An exercise program was designed that included trunk and postural muscle exercises to keep body straightened that took 20- 30 minutes per session. Group exercise sessions were held once a week being supervised by a physical therapist in hospital for 24 weeks. The presence of the physical therapist permitted the progress of the participants to be monitored on an individual basis. Subjects were recommended to perform this program at least three times per week at home.

Three sets of 10-repetition exercises included 1) flattening back exercise and sit-up exercise in supine; 2) hip muscle strengthening exercises; 3) trunk extension exercises with four levels of difficulties in prone (one level per month); 4) arm extension with manual resistance from the contralateral hand in prone; 5) trunk flexion/extension exercises at hands-and-knees position; 6) raise one arm and contralateral leg at hands-and-knees position; 7) postural exercises in standing position, such as slowly sliding down along the wall, upper back extension while upper limbs in elevation (V shape) and in horizontal abduction (W shape). Three to a maximum of ten seconds hold was asked for each exercise at the terminal range.

Data Analysis and Statistics

All data were expressed as mean ± SD and analyzed using the Statistic Package for Social Science (SPSS for Windows release 8.0, SPSS Inc. Chicago, IL). Two-tailed paired t-test was used to compare the pretest and posttest data. The differences between pretest and posttest of all measurements in both groups were calculated and analyzed by unpaired student' s t-test. ANOVA with repeated measures was used to detect any difference in physical activity and calcium intake during the study periods. An alpha value of 0.05 was used for statistical analyses.

四、結果(Results)

Table 1 shows the physical characteristics of two groups. There were no significant differences in any of the basic characteristics of both groups ($p>0.05$). There were five subjects in the exercise group (35.7%) and seven in the control group (50%) who did not receive any treatment for osteoporosis. Four subjects in the exercise and five in the control group took estrogen therapy.

Baseline data of BMD and physical assessment of two groups before are in Table 2, while the measurements of two groups after 24 weeks are in Table 3. None of the initial testing variables showed significant differences between groups. Exercise group had significant improvements in BMD of L2-4, number of sit-ups and push-ups in one minute, strength of knee extensors, and maximal oxygen consumption after 24 weeks, while decreases in strength of knee extensors and endurance of trunk flexors were noted in control group. While both groups had no significant changes in physical activity and calcium intake during this period of study.

Significant between-group comparisons were noted in BMD of L2-4, strength of knee extensors, trunk flexor endurance, and number of sit-ups. The increase in spinal BMD in exercise group was significant compared to the control group (6.3 vs 1.9%, p<0.05).

五、討論(Discussion)

Physical activity and exercise have been recommended to postmenopausal women for the cardiovascular and bony benefits. Previously reported studies of exercise interventions showed conflicting results. Most studies used weight-bearing activities. Our previous study found that treadmill and stepping exercise were effective to improve BMD of femoral neck, but not that of L2-4 [8]. Obviously the weight did not load on the lumbar spinal vertebras to improve BMD L2-4. Posture might be the one of the reasons we hypothesized. Sinaki et al. have demonstrated that a significant positive correlation was found between L2-L4 BMD and back extensor strength, even when BMD was corrected for age [2]. In addition, back extensor strength was proved to be an important determinant of posture in healthy women that was negatively related to thoracic kyphosis and positively correlated with lumbar lordosis and sacral inclination [11]. Therefore, we designed a postural exercise program, mainly working on the trunk and hip muscles and may be the lower extremity muscles with emphasis on keeping good posture in daily activities in this study and investigate the effects on BMD.

Researchers have studied back exercise program that was able to increase back extensor strength, but ineffective in retarding vertebral bone loss in ambulatory, healthy postmenopausal women [5]. Smidt et al. found no significant differences in BMD between the exercise and control groups at lumbar vertebraes at baseline, 6-month, and 12-month evaluation sessions. However, strength in prone trunk extension and double leg function increased [12]. Similar findings were demonstrated by Hartard et al.. Training group (twice per week) increased strength but not the BMD, whereas the control group demonstrated a significant loss of BMD, especially in the femoral neck [13]. On the other hand, several studies have shown positive effects of strength training. Colletti et al. demonstrated that muscle-building exercise was associated with increased BMD at the lumbar spine (1.35±0.03 vs. 1.22±0.02 g/cm2, p< 0.01), trochanter (0.99± 0.04 vs. 0.86±0.02 g/cm2, p< 0.01), and femoral neck (1.18± 0.03 vs. 1.02 ±0.02 g/cm2, p< 0.001) [14]. Some researchers believed that a higher magnitude of resistance training was necessary to stimulate osteogenesis at the spine [15]. Rhodes and associates did one year of resistance training in elderly women and found significant strength changes that paralleled changes in BMD, however, the correlation coefficients were only moderate [16]. Our study demonstrated 6.3% improvement of L2-4 BMD in exercise group. That indicated that our exercise program via muscle action or mechanical loading from improved posture had a more profound site specific effect. In addition, a significant correlation between the improvement of L2-4 BMD and number of sit-ups (r=o.566, p<0.05) was found. However, the mechanism of the correlation is not clear. Further studies are needed.

Tan and associates found that the isokinetic strength of hip muscles did not contribute to the bone mineral density of the proximal femur [17]. In addition, Sinaki et al. demonstrated that BMD of Ward's triangle correlated with spinal extensor strength (r=0.25). Therefore, we did not test the strength of hip muscles. The significant differences we found between exercise and control group were BMD of L2-4 and strength of right knee extensors and trunk flexors. Knee extensor strength has been used as the index of general strength. This may be coincident with the conclusion of Sinaki's study, the effect of muscle strength on bone mass was more systemic than site-specific [18]. Sinaki and associates have reported that no significant effect of the loading and non-strenuous strengthening exercises in the exercise group or control group on BMD at the spine or hip measurement sites. Our study agreed with theirs about the BMD of proximal femur.

Few studies investigated BMD of distal femur. Some reported it was negatively related to the osteoarthritis. We included the BMD measurement of this site in attempt to the study the site-specific effect of muscle strength. Our study showed that exercise group improved in knee extensor strength, however, not in BMD of distal femur. It appeared that our findings again in favor of the systemic effect of muscle strength.

Table 1. Initial physical characteristics of the groups.

	Exercise group	Control group
Age (yr)	59.4±5.6	57.5±3.9
Ht (cm)	154.54±4.58	155.61±5.74
Wt (kg)	55.68±6.18	54.11±6.02
BMI(kg/m^2)	23.48±3.11	22.52±2.66
Menopause (yr)	10.5±5.6	9.2±5.6
EE^1(Cal/d)	2155.8±675.3	2074.6±332.1
TCI^2 (mg/d)	762.3±487.8	682.3±441.1

[1]indicates energy expenditure; [2] indicates total calcium intake

Table 2. Measurements of two groups at Baseline

	Exercise Gr	Control Gr
BMD		
Spine (L2-4)	0.759±0.105	0.820±0.069
Femoral neck	0.702±0.084	0.705±0.089
R knee	0.999±0.146	0.975±0.088
Muscle Strength (N-m)		
R quadriceps at 90°	92.2±23.3	133.9±42.7
Trunk flexor at 0°	70.1±17.2	73.0±24.8
Trunk extensor at 0°	60.9±28.6	66.4±33.8
Muscular endurance(%)		
R quadriceps	73.7±15.1	71.6±7.2
Trunk flexor	80.6±23.7	94.1±4.6
Trunk extensor	82.1±20.3	83.7±10.5
Sit-up (no./min)	10.2±11.3	10.0±8.6
Push-up (no./min)	24.4±6.2	30.5±5.3
Body fat (%)	32.71±8.08	30.00±8.97
Fat free mass (kg)	37.35±5.72	37.92±5.63
VO_2max (ml/kg/min)	16.23±2.49	16.48±3.22

Table 3. Measurements of two groups after 24 weeks

	Exercise Gr	Control Gr
BMD		
Spine (L2-4)	0.804±0.097*	0.833±0.059#
Femoral neck	0.708±0.082	0.722±0.048
R knee	1.017±0.119	0.979±0.109
Muscle strength (N-m)		
R quadriceps at 90°	108.9±23.9*	119.1±34.3*#
Trunk flexor at 0°	61.0±17.5	74.7±30.5#
Trunk extensor at 0°	77.7±21.2	71.6±24.7
Muscular endurance(%)		
R quadriceps	67.7±10.2	70.1±9.9
Trunk flexor	88.8±8.6	85.5±9.3*
Trunk extensor	78.6±16.2	80.6±11.3
Sit-up	21.7±9.2*	12.0±12.7#
Push-up	32.8±8.1*	36.7±9.3
Body fat (%)	31.86±6.43	28.86±9.06
Fat free mass (kg)	38.05±5.17	38.71±5.33
VO_2max (ml/kg/min)	18.69±3.73*	18.36±4.95

* comparison of pre-test and post-test within groups, $p < 0.05$; # comparison of between group changes (posttest –pretest)

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