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Original Article

Effect of Tai-chi exercise on lower limb muscle strength, bone mineral density and balance function of elderly women

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Abstract: To study the effect of Tai-chi exercise on lower limb muscle strength, bone mineral density and balance function of elderly female, 105 urban elderly women, who do insufficient exercise in daily life, are selected as the subject and randomly divided into an observation group (Tai Chi Group), a control group I (Dance Group) and a control group II (Walking Group). Each group is consists of 35 women. Among them, the women in the observation group do Tai-chi exercise once a day, while the women in the control group I dance once a day and in the control group II stick to brisk walking once a day. All women in the three groups do the above said exercises for 40 minutes and the exercise intensity is controlled to be medium. At the time of selection and after 4, 8 and 12 months upon their exercises, respectively detect and compare the lower limb skeletal muscle mass, lower limb muscle strength, bone mineral density and balance function of the subject. Results: At the time of selection, the general information of the subjects in the three groups show no significant difference ($P > 0.05$); however, after 4 months' exercise, most of the study indexes in the control group I and group II are improved significantly ($P < 0.05$), while most of the study indexes in the observation group show no significant difference ($P > 0.05$) in comparison with those at the time of selection and their general improvement effect is slightly lower than that in the control group; after 8 months, relevant study indexes of the subjects in the three groups are significantly improved ($P < 0.05$) in comparison with those at the time of selection, especially, the effect in the observation group is more obvious and is better than that of the control group II ($P < 0.05$). 12 months later, the effect of the observation group is improved significantly from day to day when comparing to theose in the control group I and group II ($P < 0.05$ or $P < 0.01$). Conclusion: Compared with the senile dance and walking exercises, the short-term Tai-chi exercise effect is not obvious, however, once the exercise period is extended, that is, continuous exercise for 8 months or even above 12 months, the advantage of Tai Chi is more and more significant. The study suggests that as a fitness measure, Tai Chi is more suitable for long-term exercise and its short-term effect is not obvious.

Keywords: Tai-chi, elderly women, lower limb muscle strength, bone mineral density, balance function

Introduction

As for the post-menopausal women, because their estrogen levels and the content of bone are reduced and the bone micro mechanism is changed, the onset rate of osteoporosis is higher than that of their male peers at the same age. This phenomenon is called postmenopausal osteoporosis and it is the prevalent disease among the senile women [1, 2]. At the same time, with the increase of the age, the elderly people may experience obvious degenerative changes, for example, the body function, morphology and structure, as a result, both their muscle strength and proprioception decline. Consequently, their balance function is feeble and it seriously restricts their walking function or daily activities. Relevant study confirms that except illness, physical and physiological function decline and genetic factors, the reasons why the elderly people suffer poor walking function involve their daily fitness and exercise habits [3]. It is reported that the important factors, resulting in poor walking function and teeter of the elderly people, are muscle atrophy, poor lower limb muscle strength and

Table 1. Comparison of General Information for the Selected Objects in the Three Groups at the Time of Selection ($\bar{x} \pm s$)

Group	Gender	Cases	Age	Height (cm)	Weight (kg)	Total exercise time of each week (min)	Exercise number of each week (number)
Control group I	Female	33	61.83 ± 4.37	159.31 ± 8.42	58.24 ± 7.53	51.27 ± 6.46	≤ 2
Control group II	Female	30	62.85 ± 5.29	157.64 ± 7.31	56.81 ± 6.09	54.04 ± 6.87	≤ 2
Observation group	Female	31	62.14 ± 5.52	158.37 ± 7.31	57.65 ± 8.12	53.26 ± 7.51	≤ 2

Note: $P > 0.05$.

coordination function [4]. The necessary exercise means can improve their body function and balance function and then the walking function [5, 6]. In this study, the two common fitness means for the elderly people, the senile dance and brisk walking, are used in the control groups. Through the practice and comparative study, it is to observe effect of Tai-chi exercise on lower limb skeletal muscle content, lower limb muscle strength, bone mineral density and balance function.

Materials and methods

Study data

105 elderly women, 55-65 years old, are selected from 5 communities in Jiaozuo City. Inclusion criteria: through the investigation of personal data, all the selected women rarely do limb exercise in their daily life (exercise times < 2 times each week and the exercise time < 30 minutes for each time); walking function is significantly lower than that of their peers; but they enjoy good spirits, without limb motion obstacle. Exclusion criteria: they don't suffer Parkinson's disease, Alzheimer's disease, traumatic brain injury, stroke, except lower limb joint fracture and severe pain or disease. Unfortunately, they are affected with heart disease, hypertension, vertigo and other diseases. Meanwhile, they are not convenient for exercise. All subjects consent to the study. 105 women are randomly divided into an observation group (Tai Chi Group), a control group I (Dance Group) and a control group II (Walking Group), each of which consists of 35 women. During 12 months' exercise period, it eliminates the abandoned practice exercise. A total of 11 women are excluded. Among them, 4 women in the observation group are canceled, 2 women in the control group I and 5 women in the control group II. 31 women in the observation group participate in the exercise, 33 women in the control group I and 30 women in the control group II. In the general data statistical aspect, as far as 3 groups of subjects are concerned, $P > 0.05$. There is no statistically significant difference among the groups and they are comparable. See **Table 1**.

Study methods

(1) Literature method: By inquiring about literatures, understand the related data of elderly female, such as physical characteristics, bone density, muscle strength, balance and walking functions, identify the relationship among walking function indexes of the old people and the related factors affecting their walking function, at the same time, select the methods to detect the indexes such as bone density, muscle strength of lower limbs, skeletal muscle content and balance function.

(2) Investigation method: By questionnaires, consulting and other methods, investigate the personal data of 55-65 years old female in the study area and select a total of 105 elderly women who meet the study conditions.

(3) Experimental method: 105 selected women are randomly divided into a Tai Chi Group, a dance group and a walking based on the figure table method, each of which consists of 35 women. The Tai Chi group does Tai Chi exercise. For the specific exercise content and measures (see *Chen Style Tai Chi Healthcare* Tutorial Book and its attached CD). The dance group selects the senile Fancy Gymnastics audio and video products created by Zhejiang Province Gymnastics Association as training material; the brisk group chooses the brisk walking exercise. The selected women in the three groups do the exercise for 40 minutes once a day, 6 days for a week. The exercise intensity is controlled to be medium. In other words, during the exercise process, the heart rate of selected women is about 120 times/min and they do continuous exercise for a total of 12 months.

Detection of indexes

(1) Bone density detection: use DPX-NTDXA ultrasound bone mineral density instrument produced by USA Lunar Company for the bone density detection. USA National Institutes of Health (NIH) study conclusion confirms that bone density is an important index for detection of body mass and screening for osteoporosis, while calcaneus is the best detection position for detection of the bone density, thus the detection position is the calcaneus in this study.

(2) Detection of the lower limb muscle strength: detect it with BiodexSystem3Pro isokinetic muscle strength testing instrument produced by USA. Detection items are the muscle strength in the hip extensor of the lower limbs, knee extensor and talocrural (ankle) joint dorsiflexion; data acquisition: record the data output by the instrument and detect each item at left and right side of the body for continuous 3 times and then take the mean value from the highest value at left and right side in each item.

(3) Detection of the lower limb skeletal muscle content: detect it with JS7-G65- body composition analyzer produced by USA. Measurement methods: subjects, who wear the light clothing and remove belongings, are tested by the specially-assigned person in accordance with the instrument specifications; data acquisition: the data of lower skeletal muscle content (kg) at left and right side is directly tested by the body composition analyzer in the set programs of the machine and then their mean value is taken.

(4) Detection of the balance function: detect the dynamic balance function when the subjects close their eyes and step in place, in other words, the subjects stand in a center of a circle with 40 cm diameter and close their eyes. Once they hear "start" command, they immediately step in a frequency of 120 steps per minute until their foot out of or in contact with the circle. The duration time was recorded in a unit of second. The longer the duration, the better the dynamic balance function; USA a dynamic balance test system produced by USA to detect the dynamic balance function of the subjects. It is required that the subjects shall stand on the test bench, without wearing the shoes, both hands droop naturally, heels put together, feet toes separate and stand at 30 degree, while open eyes to focus on the dynamic balance tester screen, if necessary, adjust the body to move the indication dot on the screen to cross axis center. The test time is 30 seconds. Detection of comprehensive shake indexes (degree), front and back shake indexes (degree) and wavered index (degree): the higher the shake indexes, the worse the balance function. The detection time of the above indexes is respectively listed as follows: before the subjects doing exercise, after 4, 8 and 12 months' exercise.

Statistical analysis

This study uses SPSS13.0 to process the data and the data obtained is expressed in ($\bar{x} \pm s$). Adopt t to detect when comparing the measurement data. In case of $P < 0.05$, it means that the difference has the statistically significance.

Results

Comparison of detection indexes for the subjects in the three groups after 4 months' exercise

After 4 months' exercise, most of the study indexes in the control group I and group II are improved significantly ($P < 0.05$), while most of the study indexes in the observation group show no significant difference ($P > 0.05$) in comparison with those at the time of selection. Only the shake indexes and knee muscle strength in the balance function index are improved significantly ($P < 0.05$). After the observation group does exercise, respectively compare its improvement effect with those in the control group I and group II and it shows no obvious difference among groups ($P > 0.05$). After 4 months of exercise, the general improvement effect in the observation group is slightly lower than that in the control group (**Table 2**).

Comparison of detection indexes for the selected objects in the three groups after 8 months' exercise

After 8 months, relevant study indexes of the subjects in the three groups are significantly improved ($P < 0.05$) in comparison with those at the time of selection, especially, the effect in the observation group is better; in comparison with the improvement effect of the control

Table 2. Comparison of lower limb skeletal muscle content, muscle strength, bone mineral density and balance function indexes for the subjects in the three groups before exercise and after 4 months ($\bar{x} \pm s$)

Detection indexes	Control group I (n = 33)		Control group II (n = 30)		Observation group (n = 31)	
	Before exercise	After 4 months	Before exercise	After 4 months	Before exercise	After 4 months
Bone quality index (BQI)	71.37 ± 13.27	76.63 ± 13.91	70.81 ± 14.75	76.52 ± 15.46	71.03 ± 16.30	75.66 ± 15.48
Lower limb bone muscle content (kg)	5.69 ± 1.02	5.84 ± 1.07	5.32 ± 1.05	5.60 ± 1.04*	5.53 ± 1.09	5.67 ± 1.06
Hip extension strength (N)	206.26 ± 31.37	217.30 ± 32.17*	199.76 ± 29.25	214.33 ± 28.54*	203.19 ± 30.35	209.46 ± 29.88
Knee extension strength (N)	181.52 ± 28.71	192.30 ± 29.04*	177.97 ± 27.55	189.46 ± 28.02*	179.35 ± 29.01	190.62 ± 28.79*
Talocrural joint dorsal flexion strength (N)	101.86 ± 20.39	113.41 ± 20.58*	100.91 ± 19.75	115.07 ± 21.18*	101.29 ± 22.37	108.72 ± 21.81
Comprehensive shake index (°)	5.22 ± 0.91	4.71 ± 0.84*	5.30 ± 0.92	4.70 ± 0.90*	5.28 ± 0.89	4.72 ± 0.90*
Front and back shake index (°)	4.42 ± 0.76	4.05 ± 0.58*	4.50 ± 0.80	4.01 ± 0.78*	4.47 ± 0.75	4.01 ± 0.74*
Wavered index (°)	3.46 ± 0.58	3.02 ± 0.56*	3.48 ± 0.60	3.02 ± 0.59*	3.50 ± 0.60	3.07 ± 0.58*
Eyes closed and stepping in place (s)	6.09 ± 3.12	6.97 ± 3.24*	6.11 ± 3.30	7.28 ± 3.42*	6.10 ± 3.29	6.45 ± 3.27

Note: Comparison of the subjects in the three groups after and before exercise, $^{*}P < 0.05$.

Table 3. Comparison of lower limb skeletal muscle content, muscle strength, bone mineral density and balance function indexes for the subjects in the three groups before exercise and after 8 months ($\bar{x} \pm s$)

Detection indexes	Control group I (n = 33)		Control group II (n = 30)		Observation group (n = 31)	
	Before exercise	After 8 months	Before exercise	After 8 months	Before exercise	After 8 months
Bone quality index (BQI)	71.37 ± 13.27	78.86 ± 14.05[a]	70.81 ± 14.75	78.31 ± 15.70[a]	71.03 ± 16.30	79.27 ± 15.78[a]
Lower limb bone muscle content (kg)	5.69 ± 1.02	5.89 ± 1.12[a]	5.32 ± 1.05	5.75 ± 1.09[a]	5.53 ± 1.09	5.90 ± 1.08[a]
Hip extension strength (N)	206.26 ± 31.37	225.30 ± 32.45[a]	199.76 ± 29.25	219.39 ± 27.90[a]	203.19 ± 30.35	231.55 ± 29.94[a,b,c]
Knee extension strength (N)	181.52 ± 28.71	203.57 ± 28.81[a]	177.97 ± 27.55	195.74 ± 27.91[a]	179.35 ± 29.01	213.55 ± 28.30[a,b,c]
Comprehensive shake index (°)	5.22 ± 0.91	4.38 ± 0.81[a]	5.30 ± 0.92	4.42 ± 0.91[a]	5.28 ± 0.89	4.01 ± 0.88[a,c]
Front and back shake index (°)	4.42 ± 0.76	3.94 ± 0.56[a]	4.50 ± 0.80	3.97 ± 0.79[a]	4.47 ± 0.75	3.55 ± 0.73[a,b,c]
Wavered index (°)	3.46 ± 0.58	2.77 ± 0.51[a]	3.48 ± 0.60	2.85 ± 0.55[a]	3.50 ± 0.60	2.62 ± 0.53[a,c]
Eyes closed and stepping in place (s)	6.09 ± 3.12	8.03 ± 3.26[a]	6.11 ± 3.30	7.80 ± 3.44[a]	6.10 ± 3.29	8.96 ± 3.40[a,c]

Note: Comparison of indexes for 3 groups of subjects after and before exercise, $^{a}P < 0.05$; comparison of the observation group with the control group I after exercise, $^{b}P < 0.05$; comparison of the observation group with the control group II after exercise, $^{c}P < 0.05$.

Table 4. Comparison of lower limb skeletal muscle content, muscle strength, bone mineral density and balance function indexes for the subjects in the three groups before exercise and after 12 months ($\bar{x} \pm s$)

Detection indexes	Control group I (n = 33)		Control group II (n = 30)		Observation group (n = 31)	
	Before exercise	After 12 months	Before exercise	After 12 months	Before exercise	After 12 months
Bone quality index (BQI)	71.37 ± 13.27	79.02 ± 14.37[a]	70.81 ± 14.75	78.50 ± 15.82[a]	71.03 ± 16.30	81.54 ± 15.71[a,c]
Lower limb bone muscle content (kg)	5.69 ± 1.02	5.94 ± 1.13[a]	5.32 ± 1.05	5.87 ± 1.10[a]	5.53 ± 1.09	5.95 ± 1.11[a,c]
Hip extension strength (N)	206.26 ± 31.37	230.51 ± 33.07[a]	199.76 ± 29.25	224.75 ± 27.94[a]	203.19 ± 30.35	242.51 ± 29.97[a,b,c]
Knee extension strength (N)	181.52 ± 28.71	212.49 ± 28.11[a]	177.97 ± 27.55	204.58 ± 27.64[a]	179.35 ± 29.01	225.79 ± 27.92[a,b,c]
Talocrural joint dorsal flexion strength (N)	101.86 ± 20.39	126.93 ± 22.05[a]	100.91 ± 19.75	121.40 ± 21.71[a]	101.29 ± 22.37	134.91 ± 22.12[a,c]
Comprehensive shake index (°)	5.22 ± 0.91	4.17 ± 0.73[a]	5.30 ± 0.92	4.29 ± 0.85[a]	5.28 ± 0.89	3.70 ± 0.88[a,b,c]
Front and back shake index (°)	4.42 ± 0.76	3.41 ± 0.54[a]	4.50 ± 0.80	3.71 ± 0.76[a]	4.47 ± 0.75	3.11 ± 0.71[a,b,c]
Wavered index (°)	3.46 ± 0.58	2.51 ± 0.48[a]	3.48 ± 0.60	2.72 ± 0.53[a]	3.50 ± 0.60	2.20 ± 0.53[a,b,c]
Eyes closed and stepping in place (s)	6.09 ± 3.12	8.97 ± 3.31[a]	6.11 ± 3.30	8.26 ± 3.51[a]	6.10 ± 3.29	9.55 ± 3.49[a,b,c]

Note: Comparison of indexes for 3 groups of subjects after and before exercise, [a]$P < 0.05$; comparison of the observation group with the control group I after exercise, [b]$P < 0.05$; comparison of the observation group with the control group II after exercise, [c]$P < 0.05$ or $P < 0.01$.

group II, most indexes are improved significantly ($P < 0.05$); in comparison with the improvement effect of the control group I, the individual index shows the obvious difference ($P < 0.05$). The general improvement effect in the observation group is better than that of the control group II and group I (**Table 3**).

Comparison of detection indexes for the selected objects in the three groups after 12 months' exercise

12 months later, the effect of the observation group is improved significantly from day to day, in comparison with that at the time of selection, $P < 0.05$ or $P < 0.01$; in comparison with that in the control group I, most of the indexes is significantly better than that of control group I, $P < 0.05$; in comparison with that in the control group II, most of the indexes show significant difference, $P < 0.05$ or $P < 0.01$. The general improvement effect in the observation group is better than that of the control group II and group I, while some of indexes are significantly better than those of the control group II (**Table 4**).

Discussion

Biomechanics and physiology study data confirms that regular exercise can create a new bone stress environment and the lower limb movement can especially make longitudinal bone under constant stress stimulation. The mechanical signals is transferred into the biochemical signals that can promote bone formation, so that the bone blood circulation is improved and the bone becomes more sturdy and durable [7, 8]. Other studies also suggest that aerobic exercise can promote positive changes in endocrine, growth hormone, sex hormone and secretion of other bone growth factors, as a result, promote bone salt calcification and deposition and strengthen bone [9-11]. At the same time, the three moderate intensity exercises, for example, Tai-chi , senile dance and brisk walking, are aerobic, thus, it is helpful for improving osteoporosis and strengthening tendons and bones. As everyone knows, the movement function of the old people, especially lower limb movement and balance function, is affected by the bone mass, besides, the muscle strength of lower limbs also plays an important role. Most of the studies report that muscle strength and balance function decrease significantly, especially significant decline of lower limb muscle strength is an important reason for poor walking function and falling of the old people [12, 13]. For example, studies show that the long-term fitness and walking exercise can improve the walking function of old people [14]. Other reports show that through the necessary functional rehabilitation training means, such as the sports and exercises for improving balance and muscle strength, it can effectively maintain the good conditions of sports balance organs and muscle tissues, which has important significance on improving the walking function, preventing falls and curing some movement disorders [15, 16]. In the report about Tai-chi and the balance function of the old people, it points out that key knee and ankle key strength is the decisive factor to maintain body balance. In Tai-chi exercise process, the movement posture- the dip of knee can stimulates the leg muscles, especially, obvious stimulation on ligament around the knee and ankle [17-19]. This stimulation can not only increase muscle strength but also the motion range of knee and ankle joints, for example, increase of ankle plantar flexion and dorsiflexion torque force. For this reason, the old people, who insist on doing exercise for a long time, have the better balance and walking functions than their peers who lack the daily fitness exercise.

In the study, it provides practical studies for the exercise means used by the old people, such as Tai-chi, senile dance and brisk walking. Through comparing relevant study indexes for 3 groups of subjects after their 4, 8 and 12 months' exercise, discuss the advantages and disadvantages of Tai Chi for the effect of Tai-chi on the old people. It is known from data in **Tables 2-4** that after 4 months' exercise, the individual index among muscle strength of lower limbs, skeletal muscle content and balance function of the people from the dance group and the walking group, is improved obviously, while the knee extension strength and a part of balance function indexes in Tai Chi group are improved obviously. The general improvement effect is worse than that of the dance group and the walking group; but after 8 months' exercise, the effect of Tai Chi group is more and more significant in comparison with the dance group and the walking group, especially, 12 months' later, its effect shows significant difference. In compari-

son with the effect before exercise and that of the control group, $P < 0.01$ or $P < 0.05$, and the difference has statistically significance. The reasons may be related to the following factors: Tai-chi exercise focuses on transformation between deficiency and excess, while the upper and lower limbs, trunk and internal organs are full of deficiencies and excesses. For example, if the leg undergoes the transformation between deficiency and excess, the lower limbs can obtain obvious muscle strength training, which can enhance the lower limb strength; besides, the muscles and ligaments of foot can get enough exercise. With the pass of time, it not only can correct flat feet, but also can improve the arch flexibility. At the same time, Tai-chi movement focuses on the full-body exercise and all parts are linked together. When moving the waist, knee and joint, in coordination with convolution and winding movement, the shoulder, elbow, knee, hip, ankle, wrist and other joints can steadily activate the whole body. With the help of the muscle relaxation and the joint movement, it not only can use the stiffness method skillfully, on the other hand, it also can rhythmically stress and stimulate the body muscles and bones, thus, it can achieve the effect of strengthening muscles and bones. ② The practitioners are hard to master the standard postures of Tai-chi exercise in the short term. If the posture is not standard, it not only greatly reduces the effect of Tai Chi exercise, but also injuries the knee joint, which may result in pain of the knee joint. On the contrary, the senile-dance and brisk walking exercises don't have complex motion requirements, thus it is easy for short-term practice and implementation. For this reason, the short-term exercise effect of Tai Chi is inferior to that of the dance group and walking group. With the gradual standard and smooth of of motion essence, its advantages gradually become more and more obvious. In a summary, the results of this study suggest that in comparison with the senile dance and walking exercise, short-term Tai-chi exercise effect is not obvious, which is related to poor proficiency, insufficient in skill, strength conversion and grasp function. With extension of the exercise period and enhancement of Tai-chi exercise level, the fitness effect will be better than that of the dance and walking. Therefore, as a fitness means used by the old people, Tai-chi is not suitable for short-term training but for the long-term practice.

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Disclosure of conflict of interest

None.

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