Effects of Circuit Aerobic Step Exercise Program on Musculoskeletal for Prevention of Falling and Enhancement of Postural Balance in Postmenopausal Women

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Objective: *The objective of this research was to develop a circuit aerobic step exercise program and to examine the effects of the circuit aerobic step exercise program on bone formation, bone resorption, muscle strength and body balance of the postmenopausal females.*

Material and Method: *The samples consisted of 52 female participants from Chulalongkorn University, aged between 45-55 years old. The subjects were divided into two groups: 26 females in the circuit aerobic step exercise group (CASE) and 26 females in the control group (CON) by the simple random sampling method. The experimental group participated in the aerobic step exercise program while wearing heart rate monitors. The exercise speed was determined by the rhythm of the music. The experimental group completed two circuits of aerobic step exercise at 6 stations, 3 times per week, for a period of 4 weeks. The intensity is 55-75% of a maximum heart rate. The control group did not participate in the circuit aerobic step exercise program. The collected data of the before and after experiment were the results of physiology test, biochemical bone markers, muscle strength and balance ability. The collected data were compared and analyzed by the mean and standard deviation. The differences of the tests were statistically significant at the 0.05 level.*

Results: *After the 4-week experiment training, the circuit aerobic step exercise group had significantly decreased in resting heart rate and bone resorption ($p<0.05$). Muscle strength and balance on normal stability surfaces improved significantly only in the circuit aerobic step exercise group when being compared with the pretest and the control group ($p<0.05$).*

Conclusion: *The circuit aerobic step exercise had positive effect on bone formation, muscle strength and body balance. This, therefore, is a good exercise choice for postmenopausal people and can help reduce the risks of falling especially in postmenopausal women.*

Keywords: *Biochemical bone marker, Bone formation, Circuit aerobic step exercise, Balance, Falling, Postmenopausal women*

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Osteoporosis is often found in the elderly, especially aged women. It is due to the changing biochemical mechanism particularly the decrease of estrogen levels. Postmenopausal women run a high risk of developing osteoporosis as the growth rate of bone mass has been gradually reduced[1]. The factors concerning age-related condition lead to the deterioration of the muscle system and physical structure resulting in body balance[2]. As a result, these women are prone to fall, leading to bone fractures or even paralysis. So their quality of life becomes poor[3]. The main objective of avoiding bone fractures at present, therefore, focuses on the reduction of falling, the maintenance of bone condition or the development of bones by strengthening the body muscles through exercise which seems to be the best solution[4]. Many studies[4-8] revealed that the impact exercises as jumping and step aerobics affected the development of bone mass, muscle strength and balance stability of pre- and postmenopausal women. Some previous studies[4-6] claimed that long term impact exercise affected in reducing bone resorption and improving balance in elderly people. However, there was no research on

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combined impact (step aerobics) and circuit exercises on the multiple risk factors of fractures (biochemical bone markers, lower extremity strength and stability) in postmenopausal women. This research placed an emphasis on the short duration (4 weeks) of circuit aerobic step exercise program on musculoskeletal and body stability. The aerobic impact exercise and the circuit exercise were combined to shorten the training time frame.

The present study aimed to develop a circuit box jumping exercise program and to examine the effects of the circuit aerobic step exercise program on biochemical bone markers, muscle strength and balance of the postmenopausal females. The results achieved would encourage better understanding of how circuit aerobic step exercise training could interact with the physiological systems associated with bone turnover and remodeling. The findings from this study would serve as guidelines for women to maintain good health, prevent osteoporosis, develop body stability, and reduce instances of falling that lead to fractures.

Material and Method

Subjects

The study employed an experimental research design conducted on 52 female participants at the age of 45-55 working at Chulalongkorn University in Bangkok. Participants' health history and general qualifications were evaluated before screening for the exercise program. The selection instruments were a subject selection form and the SAHARAR BMD to measure the heel bone density (BMD). All participants were required to have heel bone density of not lower than -2.5 of the standard deviation by using SAHARAR BMD to measure the heel bone density. The potential participants were excluded if they suffered from osteoporosis, if they were smokers, alcoholic consumers, took medications or hormones affecting bones at the time of the experiment, or if they drank more than 2 standard-sized cups (250 cc cup) of tea or black coffee per day. Moreover, they had to have a BMI not over 30. They were divided into 2 groups by simple random sampling method. Twenty-six subjects were in the CASE group and the other 26 subjects were in the control group (CON).

Exercise training intervention

The subjects in the CON group were instructed to remain sedentary while the exercise-training group started taking the circuit aerobic step exercise program. The first step of practicing this circuit aerobic step exercise program, the experimental group stretched their muscles and did the dynamic warm up/ cool down for 10 minutes before and after the training to avoid the injury. Subsequently, the exercise group completed two circuits of aerobic step at 6 stations spending 2 minutes per station three times per week for a period of 4 weeks. The aerobic step was 10 centimeters high. The intensity was 55-75% of a maximum heart rate in room temperature of 25 degree celsius. A pilot study was conducted before the project to find correlations between program intensity and music rhythm to use. The height of the aerobic step used was also taken into consideration. The modes of exercise, CASE, was validated by 5 experts and the participants who passed the test and the retest of heart rate (Polar Team 2 Pro, Polar Electro Inc., Lake Success, NY, USA and Metamax 3B, Cortex, Leipzig, Germany) while exercising before the regimes were implemented. Rhythm from music was accompanied with the exercise to assign the speed, to motivate and to increase the enjoyment through the program. The experimental group did the exercise at 17:00-17:50. However, both exercise and control groups had to control their daily food and drink consumption appropriately that may affect bone such as tea, coffee, and alcohol. Finally, the subject took the post-test.

Measurements

To measure the biochemical bone markers after 8 hours of overnight fasting, the venous blood sample was collected. Blood sampling was performed at the same time of day for the pre- and post-tests in order to avoid diurnal changes in blood chemistry variables. Two hours after having breakfast, the participants were asked to perform balance and muscle strength assessment.

General physical fitness and muscle strength measures

Before joining the project, and in the 4th week of the exercise program, the participants were tested for general physiological status, namely weight and height, resting heart rate, and blood pressure-both systolic and diastolic ("Tanita" "UM-052" model Japan, Mercury sphygmomanometer, and stethoscope). The muscle strength measurement was performed with Nautilus-type back and leg dynamometer.

Balance performance measure

To assess the participants' static balancing ability, they were tested on both hard and soft surfaces on balance plates (Force plate AM; Bertec, Columbus,

OH) with eyes open, head erect, and arms by the side of the trunk. The signal from force platform was sampled at 500 Hz. The personal computer was used to collect the data with the customized BalanceCheck-based software (BalanceCheck TM Screener and Trainer 3.3.2 by BERTEC Columbus, OH). Bertec's 3-component balance plates measured vertical force and the Center of Pressure (CoP).

Measurement of biochemical bone markers

To measure the biochemical bone markers, the blood samples were drawn and tested for β-CrossLaps, P1NP and NMID Osteocalcin both before and after the experiment. The fasting for 8 hours; nine milliliters of fasting blood was collected between 8:00-10:00 AM. The PINP (Bone formation marker), β-CrossLaps (Bone resorption marker), and NMID-Osteocalcin (Bone turnover marker)-were measured by the electrochemiluminescence immunoassay (ECLIA) method followed the direction of Elecsys PINP β-CrossLaps and NMID-Osteocalcin immunoassay (Roche Diagnostics, Switzerland).

Statistical analysis

All statistical analyses were performed by using SPSS statistical software for Windows (version 19.0, SPSS Inc., Chicago, IL, USA) to find the mean and standard deviation of the data, to compare the mean of the general physiological variables, biochemical bone markers, muscle strength and balance taking place before and after the 4-week program. The data were collected before and after the experiment and were analyzed by paired samples t-test and independent samples t-test. The significant level was set at 0.05 level.

Results

There were fifty-two subjects participating in this study. The subjects were divided into two groups who were 26 females in the exercise group and 26 females in the control group by the simple random sampling method (Table 1). After the 4-week experiment training, the findings indicated that the mean scores on bone resorption (β-Crosslaps) of the exercise group and the control group were significantly different at 0.05 level (Table 2). After the training intervention, the general physiological data of the subjects in the circuit aerobic step exercise was significantly lower in resting heart rate (p<0.05) (Table 2). The muscle strength of the subjects in the circuit aerobic step exercise was significantly higher after the training intervention (p<0.05) (Table 2). The balance stability of the subjects in the circuit aerobic step exercise was significantly better after the training intervention (p<0.05) (Table 2).

Table 1. Subject characteristics

Group	Control (CON; n = 26)	Circuit aerobic step exercise (CASE; n = 26)
Age (year)	50.94±3.30	50.67±2.95
Weight (kg)	59.32±4.5	59.24±4.0
BMI (kg/m^2)	23.55±2.8	24.0±2.3
BMD of the right heel (SD)	0.203±0.913	0.197±0.917
BMD of the left heel (SD)	0.195±0.917	0.189±0.895

Discussion

The major findings of the present study were that CASE training was effective in decreasing bone resorption (β-Crosslaps). For muscle strength and balance ability, CASE group showed greater change than the CON group. These results suggested that the CASE group had positive effect on bone resorption[9-11], muscle strength and balance. This, therefore, is a good alternative exercise for postmenopausal people and also helps reduce the risks of osteoporosis and falling in women in particular.

This research found that CASE group increased muscle strength. The strength increase was most likely caused by the fact that when the muscles work harder due to increased stress from increasing the load on the body, there is an increase in motor unit recruitment. The increase of neurotransmission to the muscles results in increasing muscle strength. In addition, large axon neuron activation also leads to greater muscle strength[12-14]. This, in turn, can cause better strength of the thigh muscles in particular as the thighs bear the weight of the body during the circuit aerobic step exercise. Furthermore, the subjects had to maintain body balance during the circuit aerobic step exercise and also the stepping motion helped improve the strength of muscles of the legs[5,6].

For the balance ability, the results showed that the balance ability of the CASE group was higher than the control group. The research[12] on the relation of muscular strength and the balance ability stated that the low level of muscular strength led to the lower ability of balance. The circuit aerobic step exercise requires balancing skill and stabilities. It also causes the

Table 2. Response of physiological data, muscle strength and balance

	(CON; n = 26)		(CASE; n = 26)	
	Pre	Post	Pre	Post
Physiological data				
Weight (kg)	59.32±4.5	59.85±4.6	59.24±4.0	57.84±4.03*
BMI (kg/m2)	23.55±2.8	23.61±2.9	24.0±2.3	23.66±2.5
HR rest (bpm)	79.33±3.3	79.53±2.9	79.26±2.0	75.85±2.5*+
SBP (mmHg)	127.5±2.5	127.7±1.5	128.7±2.7	126.5±2.4*
DBP (mmHg)	81.23±3.8	80.16±5.1	81.23±3.6	80.46±5.1
Muscle strength				
Leg strength (kg/bw)	0.91±0.08	0.92±0.07	0.92±0.08	1.15±0.09*+
Back strength (kg/bw)	0.65±0.07	0.64±0.09	0.65±0.07	0.74±0.07*
Balance				
Normal stability-eyes open (%)	85.36±2.27	85.42±2.9	85.40±2.0	89.13±2.5*+
Perturbed stability-eyes open (%)	82.35±2.7	81.90±2.4	82.79±1.5	84.14±2.4*
Anterior-posterior normal stability (cm)	1.43±0.07	1.42±0.07	1.43±0.05	1.20±0.06*+
Anterior-posterior perturbed stability (cm)	1.80±0.08	1.78±0.05	1.79±0.04	1.67±0.05*
Lateral normal stability (cm)	0.62±0.06	0.62±0.07	0.61±0.06	0.43±0.05*+
Lateral perturbed stability (cm)	0.78±0.07	0.78±0.05	0.77±0.05	0.73±0.05
Biochemical bone markers				
β-CrossLaps (ng/ml)	0.453±0.053	0.448±0.051	0.455±0.055	0.395±0.049*+
P1NP (ng/ml)	50.56±4.21	50.54±3.74	50.16±2.70	48.95±3.34
Nmid-osteocalcin (ng/ml)	20.02±0.96	20.56±0.78	20.08±0.89	21.02±1.03

* Different from the pretest, significant at 0.05 level; + Different from the control group, significant at 0.05 level

development of motor system and strengthens the muscles that consequently result in higher balance ability. This study showed that the CASE regime could improve the participants' balance when they had their eyes open on both hard and soft surfaces showing that they used visual and other proprioceptive data to stabilize the body. It is believed that this leads to improving awareness of body position caused by increased propioception in the muscles, tendons and joints from step aerobic exercise[5,6]. Moreover, improving balance could result from the improved function of the vestibular apparatus of the inner ear. This system is designed to respond to the earth's gravity and movement[4,14]. It works by locating the position of the head whether vertical or horizontal, and stabilizing it in space. Circuit aerobic step exercise training, with its up and down movements, makes use of gravity which helps develop the functioning of the vestibular apparatus. It can be concluded that when the muscles are stronger and the nervous system functions better, balance also improves[15]. This definitely helps reduce risks of fracture from falling particularly in postmenopausal women[5-7].

With respect to the biochemical bone markers, the study findings corresponded to the hypothesis that the CASE group would yield better results than CON group. After the 4-week (short-term) program, it was found that bone resorption (β-CrossLaps) of the participants in the CASE group more decreased than the before experiment data. CASE is an impact exercise and many studies[4,16] have confirmed that impact exercise is good for bone development. The weight from the body and potential energy from the earth's gravity will pass through the bones and joints, forcing the bones and joints in the legs to bear the whole body weight[17] and causing the leg muscles to contract more as they try to maintain balance while doing step aerobics. This response to activity of bone cells (osteoclasts) and the compression on the bones also increases the process of mineralization of the bones. The process results in micro-fracture that cannot be seen. The micro-fracture will stimulate osteoclast to break down the bone along with osteoblast that forms and remodels the bones[9-11]. Moreover, the circuit aerobic step exercise will be a powerful training when it involves not only speed that stresses the bone mass

but also weight bearing that stimulates bone cells leading to bone forming[17,18]. In the bone cells, osteocyte is involved with a mechanism loading called the mechano receptor. This receptor adjusts itself according to the pressure on the bone relating to the bone resorption[4,17].

The exercise program for osteoporosis prevention was conducted in many researches[4-6,8]. The findings on the work outs of impact exercise[17] and weight bearing exercise[18] showed the positive effects on bone, but there still was no clear explanation on the bone resorption reduction mechanism[4]. Similarly, it was difficult for this study to use their findings to support the research assumption of the circuit aerobic exercise training on the inhibition of the bone resorption mechanism in fact that there were several elements of limitations, e.g. sample work out models, the duration of experiment, research instruments, and age span of the samples. Nevertheless, this study found that the effects of the circuit aerobic step exercise had positive effects on slowing down the bone resorption.

There are a number of limitations in the present study that should be emphasized. First, the circuit aerobic step exercise induced short duration change (4 weeks) in biochemical bone markers. A prolonged study is warranted to explore its implication of circuit aerobic step exercise in the enhancement of bone health. Second, the subjects in the present study were not osteoporosis patients. Therefore, the results of the present study may not be generalizable to the whole population of patients with osteoporosis. As postmenopausal women are at risk of developing osteoporosis, through exercise instead of drug treatment, this would be a very beneficial alternative to drug therapy; helping them avoid it will alleviate the treatment costs both for individuals as well as the country.

In conclusion, the circuit aerobic step exercise has the positive effects on slowing down the bone resorption. It can be concluded that the circuit aerobic step exercise reduces some risks of osteoporosis in postmenopausal women. Additionally, it promotes better body balance.

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Potential conflicts of interest

None.

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ผลของการใช้โปรแกรมฝึกออกกำลังกายสเตปแอโรบิกแบบหมุนเวียนที่มีต่อระบบโครงสร้างกระดูกและกล้ามเนื้อเพื่อป้องกันการหกล้มและพัฒนาความสามารถในการทรงตัวในสตรีวัยหมดประจำเดือน

อัจฉริยะ เอนก, ณรงค์ บุณยะรัตเวช

วัตถุประสงค์: *เพื่อพัฒนาโปรแกรมการออกกำลังกายสเตปแอโรบิกแบบหมุนเวียนและศึกษาผลของการฝึก การออกกำลังกายสเตปแอโรบิกแบบหมุนเวียนที่มีผลต่อการสร้างมวลกระดูก การสลายมวลกระดูกความแข็งแรง ของกล้ามเนื้อและการทรงตัวในสตรีวัยหมดประจำเดือน*

วัสดุและวิธีการ: *กลุ่มตัวอย่างเป็นสตรีวัยหมดประจำเดือนที่มีอายุระหว่าง 45-55 ปี และเป็นบุคลากรของจุฬาลงกรณ์มหาวิทยาลัย จำนวน 52 คน มีการเลือกกลุ่มตัวอย่างแบ่งออกเป็น 2 กลุ่ม โดยแบ่งออกเป็นกลุ่มการฝึกออกกำลังกาย สเตปแอโรบิกแบบหมุนเวียน 26 คน และกลุ่มควบคุม 26 คน ด้วยวิธีสุ่มอย่างง่ายโดยกลุ่มทดลองจะฝึกออกกำลังกายสเตปแอโรบิกแบบหมุนเวียน พร้อมกับคาดเครื่องวัดอัตราการเต้นของหัวใจโดยกลุ่มทดลองจะทำการฝึกสเตปแอโรบิกแบบหมุนเวียนทั้งหมด 2 รอบวงจร โดยมีสถานีการฝึก 6 สถานี โดยมีระยะเวลาการทดลองเป็นเวลานาน 4 สัปดาห์ ๆ ละ 3 วัน ซึ่งความหนักของการออกกำลังกายคือ 55-75% ของอัตราการเต้นหัวใจสูงสุด และกลุ่มควบคุมใช้ชีวิตประจำวันตามปกติไม่ได้รับการฝึกโปรแกรมสเตปแอโรบิกแบบหมุนเวียนแล้วดำเนินการเก็บข้อมูลทั้งก่อนการทดลองและหลังการทดลองคือ ทดสอบทางสรีรวิทยา สารชีวเคมีของกระดูก ความแข็งแรงของกล้ามเนื้อและความสามารถในการทรงตัว และนำข้อมูลนำมาเปรียบเทียบและวิเคราะห์โดยหาค่าเฉลี่ยและส่วนเบี่ยงเบนมาตรฐานที่ระดับความนัยสำคัญทางสถิติที่ 0.05*

ผลการศึกษา: *ภายหลังการฝึก 4 สัปดาห์พบว่า กลุ่มออกกำลังกายสเตปแอโรบิกแบบหมุนเวียนมีค่าอัตราการเต้นของหัวใจขณะพัก และค่าการสลายกระดูก (β-CrossLaps) ลดลงอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 สำหรับค่าความแข็งแรงของกล้ามเนื้อขาค่าความสามารถในการทรงตัวบนพื้นที่มีลักษณะปกติมีค่าเพิ่มขึ้นในกลุ่ม การฝึกสเตปแอโรบิกแบบหมุนเวียนเท่านั้น เมื่อเทียบกับก่อนการทดลองและกับกลุ่มควบคุม อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05*

สรุป: *การฝึกการออกกำลังกายสเตปแอโรบิกหมุนเวียนมีผลที่ดีต่อการชะลอการสลายมวลกระดูก ความแข็งแรงของกล้ามเนื้อ และความสามารถในการทรงตัว จึงเป็นทางเลือกในการออกกำลังกายที่ดี สำหรับสตรีวัยหมดประจำเดือน และจะช่วยลดปัจจัยเสี่ยงจากการหกล้มในสตรีวัยหมดประจำเดือนได้อีกด้วย*