Effects of the Circuit Box Jumping on Bone Resorption, Health-Related to Physical Fitness and Balance in the Premenopausal Women

Achariya Anek MSc*,
Vijit Kanungsukasem PhD*, Narong Bunyaratavej MD**

** Faculty of Sports Science, Chulalongkorn University, Bangkok, Thailand*
*** Department of Orthopedics, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand*

The purpose of this research is to develop a circuit box jumping exercise program and to examine the effects of the circuit box jumping exercise program on bone formation, bone resorption, health related to physical fitness and balance of the premenopausal females. The samples consisted of 57 female volunteers from Chulalongkorn University, aged between 35-45. The subjects were divided into two groups: 28 females in the experimental group and 29 females in the control group by the simple random sampling method. The experimental group participated in the circuit box jumping 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 jumping at 6 stations with 10 jumps per station three times per week, for a period of twelve weeks. Each jumping box at Station 1 and 4 was 10 cm. high; the boxes at Station 2 and 5 were 15 cm. high; and at Station 3 and 6, the boxes were 20 cm. in height. The intensity is 60%-80% of a maximum heart rate. The control group did not participate in the circuit box jumping exercise program. The collected data before and after the experiment were the results of the physiology test, the biochemical bone markers, the health related physical fitness and the balance ability. The collected data were compared and analyzed by the mean and standard deviation. The differences of the tests are statistically significant at the .05 level.

The results of the present study are as follows;

1. After the 12-week experiment training, the findings indicated that the mean scores on bone resorption (β-Crosslaps) of the experimental group and the control group were significantly different at 0.05 level. In addition, the findings showed that the percentage changes on bone resorption (β-Crosslaps) variance of the experiment group reduced by -25.6528 %, while that of the control group reduced by -0.5933 %. Bone formation (PINP/β-Crosslaps) in the circuit box jumping subjects was significantly higher after the training intervention ($p < 0.05$).

2. The general physiological data in the circuit box jumping subjects after the training intervention was significantly lower in weight, resting heart rate and systolic blood pressure ($p < 0.05$).

3. The health-related to physical fitness in the circuit box jumping subjects after the training intervention was significantly lower in waist/hip ratio, body fat and fat in percent while skeleton muscle mass, leg strength, flexibility and VO_2max were significantly higher after the training intervention ($p < 0.05$).

4. The balance in the circuit box jumping subjects after the training intervention was significantly better after the training intervention ($p < 0.05$).

The circuit box jumping training has the positive effects on slowing down the bone resorption and consequently the bone formation increased. It can be concluded that the circuit box jumping training reduces some risks of osteoporosis in the premenopausal women. Additionally, it promotes the better health-related to physical fitness and balance.

***Keywords**: Biological marker, Bone resorption (beta CTx), Premenopause, Circuit box jumping training, Health-related physical fitness, Balance*

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Osteoporosis is often found in the elderly, especially aged women. It is due to the changing biochemical mechanism especially the decrease in estrogen levels. The multiple risks of osteoporosis are identified by estrogen deficiency[1], smoking[2], lack of proper exercises, and dietary calcium intake[3]. It is obviously accepted that many elderly have to encounter vertebrae collapse or broken bone that depends on bone accumulation. Thailand spends 4

Correspondence to:
Anek A, Faculty of Sports Science, Chulalongkorn University, Bankok 10330, Thailand.
Phone:0-2218-1002, Fax: 0-2218-1016
E-mail: ozone_aut@hotmail.com

billions baht per year on the imported medicine for osteoporosis patients while exercising is one of the best prevention behaviors of this disease. Furthermore, the elderly women have some risks such as a balancing problem which can lead to a fall and broken bones. There also are other problems occurring in muscle strength, respiratory and cardiovascular system. This research designed a circuit box jumping exercise program to strengthen the bones, muscle strength, respiratory and cardiovascular system and balance at the same time. This program can be easily used as an exercising guideline for females in order to promote good health and prevent osteoporosis.

Material and Method

Subject selection and criterion

The research design of the present study was an experimental research. The population of this study was the female Chulalongkorn University staff who volunteered to participate. The inclusion criteria were as follows: healthy premenopausal women at the age of 35-45years old, neither smoking nor alcoholic drinking, no hormonal replacement therapy (HRT), drinking tea or black coffee not more than 2 standard cups per day (250 cc/cup), doing exercise not more than twice per week, no osteoporosis (BMD not less than -2.5 SD), BMI not more than 30 kg/m^2. The subjects would be excluded if they did not continuously join the program or were injured or sick during the experiment. The subjects were divided into two groups, *i.e.* the experimental group and the control group by the simple random sampling method.

Instrument

The selection instruments were a subject selection form, a questionnaire about health, and the SAHARA^R BMD to measure the heel bone density (BMD).

The experimental instruments were a circuit box jumping exercise program which had been approved by six professionals, a heart rate monitor "Polar" brand model "M53" Finland, rhythm (using music to motivate and increase the enjoyment through the program).

The testing instruments were the physiology testing tools consisting of height measurement, scale "Tanita" "UM-052"model Japan, Mercury sphygmomanometer, and stethoscope. The testing instruments for health-related to physical fitness were a treadmill "Marathon" brand "OZ1" model, a body composition analyzer "Inbody" brand model "220", a gas analyzer "Corterx" brand "Metamax TB" model, a sit and reach box, a weight machine, and a heart rate monitor "Polar" brand "M53" model Finland. The testing instruments for bone formation and bone resorption were Elecsys 2010 "Hitachi" brand Japan, β-Crosslaps and P1NP biochemical testing of Roche Diagnostics (Thailand) Co. Ltd. Finally, the testing tool for balance ability was a balance board.

Before starting the experiment, the biochemical bone markers were tested by using the blood test in order to gain β-CrossLaps (ng/ml) and P1NP (ng/ml) value. The circuit box jumping training program's (Fig. 1) validity was verified by 6 experts and its reliability was verified by checking the heart rate of those who were within the criteria except the experimental group while practicing this circuit box jumping training program. Then, the instruments were used to collect the data. Before starting the circuit box jumping training program, both experimental and control groups had taken the pre-test by using the research instruments. After taking the pre-test, the control group continued their daily routines while the experimental group started taking the circuit box jumping training program. The first step of practicing this circuit box jumping training 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 experimental group completed two circuits of jumping at 6 stations with 10 jumps per station three times per week, for a period of twelve weeks. The jumping boxes are 10, 15 and 20 centimeters in height.

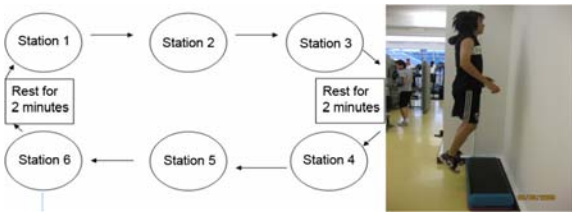

Fig. 1 Circuit box jumping training
Station 1: Jump to Box. (The jumping box is 10 centimeters high)
Station 2: Jump to Box and jump back down. (The jumping box is 15 centimeters high)
Station 3: Alternate straddle. (The jumping box is 20 centimeters high)
Station 4: Left lateral jump to box. (The jumping box 10 centimeters high)
Station 5: Right lateral jump to box. (The jumping box is 15centimeters high)
Station 6: Two-foot-side hop. (The jumping box is 20 centimeters high)

The intensity is 60%-80% of a maximum heart rate in 25 degree Celsius room temperature. The experimental group did the exercise at 17.00-17.45. However, both experimental and control groups had to appropriately control their daily food and drink consumption that may affect on bone such as tea, coffee and alcohol. In the meantime, they had to write down their diaries for 3 months in order to report thoroughly on their daily behavior. Finally, the subject took the post-test.

Statistics

The data were computer-analyzed by using the mean scores, standard deviation to test the statistical significance at 0.05 levels.

Results

There were fifty-seven subjects participating in the present study. The subjects were divided into two groups who were 28 females in the experimental group and 29 females in the control group by the simple random sampling method (Table 1). The results of the study were shown as follows: after the 12-week-experiment training, the findings indicated that the mean scores on bone resorption (β-Crosslaps) of the experimental group and the control group were significantly different at 0.05 level (Table 2). The findings also showed that the percentage changes on bone resorption (β-Crosslaps or βCTx) variance of the experiment group reduced to -25.6528%, while that of the control group reduced to -0.5933% (Table 2). The bone formation (PINP/β-Crosslaps) in the circuit box jumping subjects was significantly higher after the training intervention ($p < 0.05$) (Table 2). The general physiological data in the circuit box jumping subjects after the training intervention was significantly lower in weight, resting heart rate and systolic blood pressure ($p < 0.05$) (Table 2). The health-related physical fitness in the circuit box jumping subjects after the training intervention was significantly lower in waist/hip ratio, body fat and fat in percent while skeleton muscle mass, leg strength, flexibility and VO_2max were significantly higher after the training intervention ($p < 0.05$) (Table 2). The balance of the circuit box jumping subjects after the training intervention was significantly better after the training intervention ($p < 0.05$) (Table 2).

Discussion

Effects of the circuit box jumping exercise program on the general physiological data

The results showed that the body mass index, weight, heart rate and systolic blood pressure of the experimental group at the end of the study were lower than the collected data before the experiment. The decreasing of BMI and weight were caused by using fat as a source of energy during the exercise[4]. The increased parasympathetic nervous system led to the decreased heart rate. Additionally, the decreased sympathetic nervous system resulted in the lower resting heart rate. Systolic blood pressure was decreased because the exercise reduced the peripheral vascular resistance and enhanced the flexibility of blood vessel[4].

Effects of the circuit box jumping exercise program on health-related to physical fitness

Body composition

In the experimental group, waist to hip ratio, body fat and fat in percent were reduced by the increase of physical activity. The physical activity is body movement using major muscles such as arms, legs and back. These muscular movements cause the body to burn more energy than other normal activities[17].

Muscular strength

Jumping up and down on the boxes increased the muscular leg strength. When muscles moved with increasing strength, the motor unit recruitment and nerve impulse were also increased. As a result, the muscles

Table 1. Subject characteristics

Variable	Group	
	Control (C; n = 29)	Circuit box jumping (T; n = 28)
Age (year)	39.970 ± 3.30	39.640 ± 9.20
Weight (Kg)	55.450 ± 8.43	55.860 ± 9.20
BMI (Kg/m2)	22.975 ± 3.47	22.920 ± 3.19
BMD of the right heel (SD)	0.227 ± 0.973	0.219 ± 0.926
BMD of the left heel (SD)	0.205 ± 0.977	0.197 ± 0.883

Table 2. Responses of the biochemical bone markers, physiological data, health-related to physical fitness and balance

Variable	Group			
	Cotrol (C; n = 29)		Circuit box jumping (T; n = 28)	
	Pre-test	Post-test	Pre-test	Post-test
Physiological data				
Weight (Kg)	55.44 ± 8.73	56.03 ± 8.80*	55.85 ± 9.20	55.26 ± 9.09*
BMI (Kg/m^2)	22.74 ± 3.47	23.05 ± 3.51*	22.92 ± 3.19	22.07 ± 3.11
HR Rest (bpm)	79.10 ± 7.79	79.93 ± 7.29*	80.92 ± 8.16	77.89 ± 7.75*+
Systolic blood pressure (mm Hg)	122.89 ± 11.53	123.37 ± 10.68	122.36 ± 6.24	120.32 ± 5.69*
Diastolic blood pressure (mm Hg)	79.14 ± 9.51	78.97 ± 8.70	77.57 ± 5.32	78.21 ± 4.28
Health-Related physical fitness				
Body composition				
WHR	0.84 ± 0.04	0.85 ± 0.04	0.85 ± 0.04	0.84 ± 0.04*
Muscle mass (Kg)	20.45 ± 3.07	20.49 ± 3.05	20.75 ± 3.15	21.56 ± 3.41*
Fat mass (Kg)	18.70 ± 6.73	19.20 ± 6.81	17.67 ± 5.61	16.59 ± 5.63*
Fat (%)	31.01 ± 8.27	31.55 ± 8.17	30.79 ± 4.97	29.05 ± 4.90*
Muscle strength (1 RM)				
Leg extension (Kg)	44.65 ± 6.93	45.00 ± 6.68	43.57 ± 9.79	52.32 ± 11.66*+
Leg curl (Kg)	32.93 ± 3.89	33.10 ± 3.63	31.78 ± 4.13	36.07 ± 5.83*+
Flexibility (cm)	10.17 ± 4.29	9.38 ± 4.49	9.75 ± 5.22	13.18 ± 5.17*+
Vo_2Max (Ml/Kg/Min)	29.89 ± 4.04	30.13 ± 4.13	31.53 ± 3.43	35.78 ± 4.00 *+
Balance (Sec)	1.16 ± 0.32	1.11 ± 0.32	1.17 ± 0.32	1.66 ± 0.30*+
Biochemical bone markers				
(β-CrossLaps, bCTx) (ng/ml)	0.3628 ± 0.1324	0.3617 ± 0.1416	0.3910 ± 0.1403	0.2906 ± 0.1199*+
(P1NP) (ng/ml)	44.57 ± 11.56	37.02 ± 11.57*	45.63 ± 18.50	38.95 ± 17.31*
(Bone formation) {(P1NP)/(βCrossLaps)}x0.31	41.16 ± 12.08	34.72 ± 12.81 *	37.24 ± 12.01	43.97 ± 19.73*+

* Difference from the pretest, significant at the .05 level, + Difference from the control group, significant at the .05 level

were strengthened[4,5].

Flexibility

The flexibility of body was measured before and after the exercise program. The result showed that the flexibility of the experimental group was higher than the control group. At the warming up part during the exercise program, the subjects used their torso, hip and leg muscles. These movements resulted in increasing flexibility[6]. The flexibility of body during the warm up was more than the flexibility during the regular activities.

Endurance of cardio respiratory and maximum oxygen consumption

In comparison to the control group, the collected data of the experimental group was higher due to the circuit exercise which helped the cardio respiratory. Each jumping box station stimulated the cardiac output function and gas exchanging. The increasing of Enzymes in the oxidation process, glycogen, myoglobin, mitochondrial mass and muscle capillary led to higher VO_2max[4,17].

Effects of the circuit box jumping exercise program on balance

The results showed that the balance ability of the experimental group was higher than the control group. The research[8] 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. Jumping requires the balancing skill and stabilities. It also causes the development of motor system and strengthens the muscles that consequently result in higher balance ability

Effects of the circuit box jumping exercise program on bone formation and bone resorption

The results indicated that the designed exercise program "a circuit box jumping exercise" helped reduce

bone resorption of the premenopausal women and also stimulated bone formation. The percentage of the changes on bone resorption (β-Crosslaps or bCTx) variance of the experiment group reduced to -25.6528%, while that of the control group reduced to -0.5933%. When comparing the bone formation which was calculated by ratio of P1NP and β-Crosslaps multiply by the numerical constant 0.31 ng/ml[7], the results showed that the bone formation of the experimental group more increased than the before experiment data. This implied that the better performance by bone cells resulted in lower risks of osteoporosis. The circuit box jumping exercise program consisting of jumping on the boxes with appropriate height for the premenopausal females was a high impact exercise because the ground reaction force was sent through bones, the joints making bones and the joints of legs that bear the body weight. Then, this jumping exercise procedure caused the muscle contraction. Weight bearing and muscle contractions are likely the cause of the increased bone mass. The bone function is like Piezoelectric crystal that generates electricity in response to the applied mechanical force from jumping on the exercise boxes. 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. Moreover, the circuit box jumping 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[15]. In the bone cells, osteocyte is involved with a mechanism loading called the mechano receptor, *i.e.* a mechanism of the body responding to the mechanical pressure. This receptor adjusts itself according to the pressure on the bone that relates to the bone formation and bone resorption. The researches[9-11,17] showed that the people participating in the high impact exercise were most likely to obtain higher density of bone mass than the people who participated in the low impact exercise such as walking or non-weight bearing sports, for instance, swimming. Those researchers said that a jumping activity or other activities with high impact theoretically stimulated bone formation to reach up higher level than the lower to medium force activities did. It can be concluded that the jumping exercise improves bone health. The high impact exercise also affects the density of hip bone mass. These findings[13,14,17] consistently supported that the people who participated in the activities focusing on jumping and movement in several directions have higher bone mass than the people who participated in normal movements. The mechanism of bone remodeling unit which consisted of both bone formation and bone resorption processes was controlled by the function of osteocycle and osteoblast in the bone. Weight and force across the bone may be sensed by the osteocyte as a mechano-sensor of the bone. The osteocyte cell had a receptive sensing toward the outer weight pressing down to bones. This procedure could decrease or increase bone mass[14]. The subjects participating in the circuit box jumping training program in the present study received the benefit of weight and force through bone that stimulated osteocyte adequately to reduce the rate of bone resorption.

The exercise program for osteoporosis prevention was conducted in many researches[1,10-13,18,19].

The findings on the work outs of walking[1] and water weight bearing exercise[19] showed the positive effects on bone, but there still was no clear explanation on the bone resorption reduction mechanism. Similarly, it was difficult for this study to use their findings to support the research assumption of the circuit box jumping training on the inhibition of the bone resorption mechanism as a matter of fact that there were several elements of limitations, *e.g.* work out models of the samples, duration of experiment, research instruments and age span of the samples. Nevertheless, this study found that the effects of the circuit box jumping training had the positive effects on slowing down the bone resorption and consequently the bone formation increased. It can be stated that the circuit box jumping training reduce some risks of osteoporosis in the premenopausal women. P1NP was not significantly different, but both P1NP of the sample groups decreased. This could be explained that the process of bone remodeling mechanism had a coupling effect. Coupling means that the bone formation is linked to the bone resorption[16].

Potential conflicts of interest

None.

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ผลของการฝึกการออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนที่มีผลต่อการสลายมวลกระดูก สุขสมรรถนะและการทรงตัวในสตรีวัยก่อนหมดประจำเดือน

อัจฉริยะ เอนก, วิชิต คนึงสุขเกษม, ณรงค์ บุณยะรัตเวช

วัตถุประสงค์ *: เพื่อพัฒนาโปรแกรมการออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนและศึกษาผลของการฝึกการออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนที่มีผลต่อการสร้างมวลกระดูกการสลายมวลกระดูก สุขสมรรถนะและการทรงตัวในสตรีวัยก่อนหมดประจำเดือน*

วัสดุและวิธีการ *: อาสาสมัครซึ่งเป็นสตรีวัยทำงานที่มีอายุระหว่าง 35-45 ปี และเป็นบุคลากรของจุฬาลงกรณ์มหาวิทยาลัย จำนวน 57 คน มีการเลือกกลุ่มตัวอย่างด้วยวิธีสุ่มอย่างง่าย โดยแบ่งออกเป็นกลุ่มทดลอง 28 คน และกลุ่มควบคุม 29 คน โดยกลุ่มทดลองจะฝึกออกกำลังกายด้วยการกระโดดขึ้นลงบนกล่องแบบหมุนเวียนโดยใช้จังหวะดนตรีเป็นตัวกำหนดความเร็วในการกระโดดพร้อมกับคาดเครื่องวัดอัตราการเต้นของหัวใจ โดยกล่องมีความสูง 10 เซนติเมตร 15 เซนติเมตร และ 20 เซนติเมตร ความหนักของการออกกำลังกายคือ 60%-80% ของอัตราการเต้นหัวใจสูงสุดแต่ละสถานีจะกระโดด 10 ครั้ง มีทั้งหมด 6 สถานี กระโดดทั้งหมด 2 รอบวงจร โดยกลุ่มควบคุมใช้ชีวิตประจำวันตามปกติแล้วดำเนินการเก็บข้อมูลทั้งก่อนการทดลองและหลังการทดลอง คือ ทดสอบทางสรีรวิทยา สารชีวเคมีของกระดูก สุขสมรรถนะทางกาย และ ความสามารถในการทรงตัว โดยมีระยะเวลาการทดลองเป็นเวลานาน 12 สัปดาห์ๆ ละ 3 วัน*

ผลการศึกษา*: 1. ค่าสารชีวเคมีของกระดูกในกลุ่มฝึกการออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนดีขึ้น โดยมีค่าการสลายมวลกระดูกลดลงเมื่อเทียบกับค่าก่อนการทดลองและค่าของกลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 อีกทั้งค่าการสร้างมวลกระดูก {[อัตราส่วนระหว่างค่าการสร้างมวลกระดูก (PINP) ต่อการสลายมวลกระดูก (β-Crosslaps)] x ค่าคงที่ 0.31} ได้เพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับก่อนการทดลองและกับกลุ่มควบคุมภายหลังการทดลองอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05*

2. ค่าทางสรีรวิทยาในกลุ่มฝึก การออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนดีขึ้น โดยมีค่าน้ำหนักตัว อัตราการเต้นของหัวใจขณะพัก และความดันโลหิตขณะหัวใจบีบตัวสูงสุดลดลง อย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับก่อนการทดลองและ กับกลุ่มควบคุมภายหลังการทดลองอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05

3. ค่าสุขสมรรถนะในกลุ่มฝึก การออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนดีขึ้น โดยมีค่าอัตราส่วนเอวต่อสะโพก มวลไขมันและเปอร์เซ็นต์ ไขมันลดลงมวลกล้ามเนื้อความแข็งแรงของกล้ามเนื้อขาและสมรรถภาพการใช้ออกซิเจนสูงสุดเพิ่มขึ้นอย่างมีนัยสำคัญ ทางสถิติเมื่อเทียบกับก่อนการทดลองและกับกลุ่มควบคุมภายหลังการทดลองอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05

4. ค่าความสามารถในการทรงตัวในกลุ่มฝึกการออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนดีขึ้น โดยมีค่า ความสามารถในการทรงตัวเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับ ก่อนการทดลอง และกับกลุ่มควบคุมภายหลังการทดลอง อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05

สรุป*: การฝึกการออกกำลังกายกระโดดขึ้นลงบนกล่องแบบหมุนเวียนมีผลต่อการชะลอการสลายมวลกระดูกได้ดีขึ้น และสามารถเพิ่มแนวโน้มในการสร้างมวลกระดูกด้วย จึงเป็นผลดีต่อสุขภาพเพราะจะช่วยลดปัจจัยเสี่ยงของการเกิดโรคกระดูกพรุนของสตรีวัยก่อนหมดประจำเดือนได้ นอกจากนั้นยังช่วยสร้างเสริมสุขสมรรถนะและความสามารถในการทรงตัวที่ดี ซึ่งส่งผลให้ช่วยลดอุบัติการณ์กระดูกหักจากการหกล้มได้*