Effects of Aerobic Step Combined with Resistance Training on Biochemical Bone Markers, Health-Related Physical Fitness and Balance in Working Women

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The objectives of this research were to develop an aerobic step combined with resistance training exercise program, and to compare the effects of: A) aerobic step exercise training (STE), B) resistance aerobic exercise training (RES), C) a combined aerobic step with resistance exercise training (COM) on the health-related fitness, balance, and biochemical bone markers. Sixty participants were working female volunteers at the age of 35-45. They were divided into 4 groups by simple random sampling method. Fifteen of the participants were in the STE group, 14 in the RES group, 15 in the COM group, and 16 in the control group (CON). The STE, RES and COM exercise training programs were designed to yield the same intensity and achieve the same range of heart rate during each stage of the program. During the training, music was used to set the tempo of the workouts.

At the 8th week, it was found that resting heart rate and systolic blood pressure significantly-increased only in the STE and COM groups. After 16 weeks, the experiment results showed the significant improvement in the COM and STE groups of exercise training for β-CrossLaps, P1NP, NMID Osteocalcin and bone formation (PINP/β–CrossLaps x0.31) but not in the RES group. For balance ability, the COM group showed significantly greater change than the RES group after the training intervention ($p<0.05$).

It can thus be concluded that the STE and COM training were effective in improving bone formation (PINP/β-CrossLaps x0.31) but not in the RES group. For balance ability, the COM group showed more significant change than the RES group. Therefore, this is not only a good exercise choice for the working-age people but also it can help reduce the risks of osteoporosis and falling in women in particular.

Keywords: *Biological bone marker, Bone formation, Bone resorption, Aerobic step combined with resistance, Balance*

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Women in premenopause run a high risk of developing osteoporosis since the growth rate of bone mass has been reduced(1,11,19). The factors concerning age-related condition lead to the deterioration of the muscle system and physical structure resulting in body balance. These women are prone to falls, leading to bone fractures or even paralysis; their quality of life is consequently poor(11). The main objective of avoiding bone fractures at present, therefore, should focus on the reduction in falls, the maintenance of bone condition or the development of bones(18) by strengthening the body muscles through exercise which seems to be the best solution(9). The previous studies revealed high-intensity resistance training affected the development of bone mass, muscle mass and muscle strength of pre- and post-menopausal women(1,5-7,19).

For women in premenopause, such impact exercises as jumping and step aerobics could improve bone mass, the ability to jump and cardiovascular fitness(1,5,7,16) while high-intensity resistance training could improve bone mass, muscle mass and muscle strength(3,6,19).

However, there has not been any research on combined impact such as step aerobics and low-resistance exercises on the multiple risk factors for fractures, i.e. biochemical bone markers, lower extremity strength and stability in the premenopausal women. This research places an emphasis on the intensity of low-resistance exercise. Such exercise is easy for these

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women to do and is safe for them. They can also combine the aerobic impact exercise and the low-resistance exercise to shorten the training time frame.

Very few studies have been conducted on the issues investigating which of the two exercises proves better and whether the improvement of muscle mass after the training is related to the body stability; consequently, these issues are still debatable.

The present study aimed to compare popular types of exercise believed to help prevent osteoporosis, namely step aerobics and resistance training, and to find out whether they would yield different results from a newly-designed exercise which is a combination of the two types of exercise-aerobic step combined with low resistance training. The results achieved would encourage better understanding of how different exercise training can interact with the physiological systems associated with bone turnover and remodeling. The findings from this study can serve as guidelines for women to maintain good health and prevent osteoporosis, develop health-related fitness, and reduce instances of falls that lead to fractures. It is hoped that such an exercise regime will serve as an alternative to expensive pharmaceutical based treatments and help prevent osteoporosis in the working-age women.

Material and Method

Subjects

The study employed an experimental research design conducted on 72 participants who were female volunteers at the working age of 35-45. They were employees of Chulalongkorn University in Bangkok. The participants were selected by using the simple random sampling. The participants' health history and general qualifications were evaluated before selection for the exercise program. The selection instruments were a subject selection form, a questionnaire about health, and the SAHARAR BMD to measure the heel bone density (BMD). All participants were required A) to have heel bone density no lower than -2.5 of the standard deviation, and B) to have their bone biochemical markers assessed. The potential participants were excluded if they suffered from osteoporosis, were smokers or alcoholics, taking medications or hormones affecting bones at the time of the experiment, or if they drank more than two standard-sized cups (250-cc cup) of tea or black coffee per day. Moreover, they had to have a BMI not over 30. The selected participants were divided into 4 groups of 18. The group members were excluded if they dropped out or completed less than 80% of the training schedule. By the end of the study, the number of participants was 60: 15 are in the STE group, 14 in the RES group, 15 in the COM group, and 16 in the CON group.

Exercise training intervention

The subjects in the CON group were instructed to remain sedentary. The exercise training groups underwent 16-week exercise training programs, which involved exercising 3 days per week for 30 minutes a day. The STE group, the RES group and the COM group programs were divided into three phases: Phase 1 (week 1-2), Phase 2 (week 3-8), and Phase 3 (week 9-16). In each phase, the STE, RES and CON training programs were designed to achieve equal levels of heart rate during the respective exercise sessions. To accomplish this, the three modes of exercise were studied to determine if there was a relationship between the program intensity and the music rhythm used during the sessions. Therefore, all three groups would be trained at the same intensity and the same level of heart rate monitored by using the cardio-respiratory system named Polar Team 2 Pro (Polar Electro Inc., Lake Success, NY, USA) and Metamax 3B (Cortex, Leipzig, Germany) during each stage of the program. A pilot study was conducted before the project to find the correlations between program intensity and music rhythm used, so the three groups were trained at the same intensity and they achieved the same level of heart rate during each stage of the program. The height of the step and weight of the dumbbells used were also taken into consideration. The three modes of exercise: STE, RES and COM validated by 5 experts and the participants who passed the test and retest of heart rate while exercising before the regimes were implemented with rhythm that was used to motivate the participants and to add enjoyment through the program. Exercise intensity was increased accordingly as the subjects were fitter. During the training, music was used to set the tempo in the aerobic step and resistance training workouts. The participants wore a heart rate monitor to track their pulse. The three modes of exercise also included stretching before and after training sessions for 5 minutes.

The STE program: in Phase 1, the participants warmed up gradually to achieve 50% of the maximum heart rate within 5 minutes, maintained this intensity for 30 minutes, and then 5 minutes for cooling down, giving a total session time of 40 minutes. The participants in this phase performed the step aerobic exercises with a music tempo of 110 beats per minute on step benches with a height of 10 cm. In Phase 2, they followed the same routine to reach a range of 60-70% maximum heart rate with a music tempo of 120 beats per minute. In Phase 3, all participants performed warm-ups to achieve 60% of the maximum heart rate within 5 minutes. This was followed by performing step aerobic exercises with a music tempo of 130 beats per minute on step benches with a height of 10 cm at 70-80% maximum heart rate which intensity was maintained for 40 minutes, followed by a 5-min cooling-down period.

The RES program: in Phase 1, the participants warmed up gradually to achieve 50% of the maximum heart rate within 5 minutes and maintained this intensity for 30 minutes, followed by 5 minutes of cooling down, giving a total session time of 40 minutes. The participants in this phase performed resistance aerobic exercises with a music tempo of 115 beats per minute and raised a dumbbell with a weight of 0.50 kg. In Phase 2, they followed the same routine to reach a range of 60-70% maximum heart rate with a music tempo of 125 beats per minute. In Phase 3, all participants performed warm ups to achieve a 60% of maximum heart rate within 5 minutes, then performed low-magnitude resistance training with a music tempo of 135 beats per minute at 70-80% maximum heart rate, and maintained this intensity for 40 minutes, followed by a 5-min cool-down period.

The COM program: In Phase 1, the participants warmed up gradually to achieve 50% of the maximum heart rate within 5 minutes, maintained this intensity for 30 minutes, followed by 5 minutes for cooling down, giving a total session time of 40 minutes. The participants in this program performed the step aerobic exercises with height of 10 cm combined with raising a dumbbell with a weight of 0.50 kg, accompanied by music with a tempo of 100 beats per minute. In Phase 2, they followed the same routine to reach a range of 60-70% maximum heart rate with a music tempo of 110 beats per minute. In Phase 3, all participants performed warm ups to achieve 60% maximum heart rate within 5 minutes, then performed the COM program with a music tempo of 120 beats per minute at 70-80% maximum heart rate, maintained this intensity for 40 minutes, followed by 5-min cooling-down period.

The three modes of exercise training programs were matched between the range of heart rate and the exercise session tempo. The Committee for the Ethical Research of Human Beings approved this study on May 15, 2013.

Measurements

To measure biochemical bone markers after 8 hours of overnight fasting, the venous blood sample was collected. The 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 health-related physical fitness assessment.

Health-related physical fitness measures

Before joining the project and at the 8th and 16th weeks of the exercise program, the participants were tested for general physiological status, namely weight, height, resting heart rate, and blood pressure-both systolic and diastolic by using "Tanita" "UM-052" model Japan, Mercury sphygmomanometer, and stethoscope.

The testing instruments for health-related to physical fitness were a body composition performed by using a bioelectrical impedance analyzer called In Body 220 (Biospace, Seoul, Korea). Maximal oxygen consumption was assessed by the Modified Bruce protocol on a treadmill (Landice, Randolph, NJ, USA) in which the grade and intensity were increased every 3 minute until exhaustion. Oxygen consumption was measured with the cardiopulmonary gas exchange system (Cortex) throughout the exercise test. In assessing the maximum oxygen uptake, the participants had to pass 3 out of 4 of the following criteria: oxygen uptake alteration could not exceed 2.1 ml/kg/min (Vo2 plateau), heart rate had to be over 90% of the maximum heart rate, RER over 1.1 and RPE $\geq$18 (RPE of 6-20) (ACSM, 2013). The heart rate was measured with the Polar heart rate monitor (Polar Team 2 Pro, Polar Electro Inc., Lake Success, NY, USA). Muscle strength measurement was performed with Nautilus-type weight machines and handgrip strength tested by using a standard HANDGRIP.

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

Measurement of biochemical bone markers

To measure biochemical bone Fasting blood, blood samples were drawn and tested for β-CrossLaps, P1NP and NMID-Osteocalcin both before and after the experiment. After fasting for 8 hours, nine milliliters of 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 electrochemillu-minescence immunoassay (ECLIA) method following the direction of Elecsys PINP β-CrossLaps and NMID-Osteocalcin immunoassay (Roche Diagnostics, All bone markers are performed at Central Chulalongkorn laboratory center).

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, and compare the mean of the general physiological variables, health-related fitness and balance at week 8 and week 16. Two-way ANOVA with repeated Sheffe post hoc comparisons was used to analyze the data, and two-way ANOVA with Sheffe post hoc comparisons was used to compare the means of inter-group variables before the experiment. The means of bone biochemical variables were analyzed and compared before and after the 16-week exercise program by using a paired t-test (p<0.05).

Results

The participants were 60 working-age female volunteers, aged 35-45 years old. The participants were selected by simple random sampling and divided into four groups. Fifteen of the participants were in the STE group, 14 in the RES group, 15 in the COM group and 16 in the CON group. Table 1 showed that the demographic data of the four groups had no significant differences among the groups at the baseline. The general physiological data in the STE and COM exercise groups after the 8th week and 16th week was significantly lower in heart rate at rest and systolic blood pressure (Table 2). For body composition, there were significant changes in the three groups of exercise training after completing the 16-week experiment for waist hip ratio, muscle mass and fat mass (Table 2). At the 16th week, it was found that leg strength significantly increased only in the STE and COM groups while handgrip strength significant increased only in the RES and COM groups (Table 2). Regarding flexibility at the 8th week and 16th week, the three groups showed significant improvement in terms of flexibility measures (Table 2). Maximal oxygen consumption was significantly higher in the three-exercise groups after the training intervention (Table 2). For balance ability, the COM group showed more significant change than the RES group after the training intervention (Table 2). To measure biochemical bone markers, blood samples were drawn and tested for β-CrossLaps, P1NP, NMID-Osteocalcin and bone formation (PINP/β-CrossLaps x0.31), which showed significant enhancement only in the STE and the COM groups after the training intervention but not in the RES group (Table 3). No changes occurred in physical characteristics, physical fitness measures or biochemical bone markers, which were observed in the sedentary control group.

Discussion

The major findings of the present study are that the STE and COM training are effective in improving bone formation (PINP/β-CrossLaps x0.31) but not in RES group. For balance ability, the COM group shows greater change than the RES group. These results can suggest that the COM group may result in more positive effects in health-related fitness, balance and bone formation than the STE and the RES groups. This is, therefore, a good alternative exercise choice for the working-age people and can help reduce the

Table 1. Baseline characteristics

Variables/Group	CON (n = 16)	STE (n = 15)	RES (n = 14)	COM (n = 15)
Age (year)	41.250±3.300	39.860±3.700	40.920±4.000	40.260±3.200
Weight (kg)	57.320±4.500	58.240±4.000	57.590±5.000	58.960±4.200
BMI (kg/m^2)	23.550±2.800	24.000±2.300	24.300±2.400	23.820±1.700
BMD of the right heel (SD)	0.223±0.863	0.217±0.877	0.216±0.978	0.229±0.826
BMD of the left heel (SD)	0.212±0.876	0.199±0.893	0.215±0.973	0.207±0.873

Table 2. Response of physiological data, Health-related physical fitness and balance

	CON (n = 16)			STE (n = 15)			RES (n = 14)			COM (n = 15)		
	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Physiological data												
Weight (kg)	57.32±4.5	57.52±4.7	57.32±4.6	58.24±4.0	57.69±3.6	56.74±4.03*$^{+}$	57.59±5.0	57.17±5.1	56.87±5.1*	58.96±4.2	56.38±4.3	55.14±4.3*$^{+}$
BMI (kg/m^2)	23.55±2.8	23.76±2.8	23.78±2.9	24.0±2.3	23.55±2.7	23.16±2.5*	24.50±2.4	24.10±2.5	23.96±2.5	23.82±1.7	23.15±2.3	22.64±2.2*$^{+}$
HR rest (bpm)	79.13±3.1	79.18±3.0	79.56±2.9	78.26±2.0	77.26±2.9*	76.80±2.7*$^{+}$	79.11±3.0	78.97±3.0	78.17±2.5*	79.40±3.3	77.20±3.1*	75.20±3.1*$^{+}$
SBP (mmHg)	128.0±2.8	127.7±2.0	127.7±1.5	127.8±2.0	126.2±2.2*	125.0±2.4*$^{+}$	126.5±2.0	125.2±2.1	125.0±2.6*	127.8±2.2	126.6±2.0*	125.1±1.9*$^{+}$
DBP (mmHg)	81.43±3.6	80.25±3.5	80.56±5.2	81.73±2.6	81.66±2.8	79.46±4.1	81.57±1.9	81.85±3.03	81.64±3.2	81.13±1.8	81.46±2.3	79.73±4.0
Body composition												
WHR	0.804±0.03	0.806±0.03	0.808±0.03	0.819±0.02	0.811±0.02	0.804±0.03*	0.820±0.03	0.816±0.03	0.801±0.02*	0.817±0.03	0.802±0.03	0.790±0.03*
SMM (kg)	37.06±2.5	37.03±2.4	37.05±2.5	36.68±2.8	36.91±2.7	36.99±2.9*	36.60±3.1	36.85±3.0	36.91±2.8*	37.10±3.4	37.45±3.7*	37.66±3.5*
Fat mass (kg)	30.86±4.7	31.21±4.4	31.41±4.3	31.58±5.8	31.02±5.6	30.48±5.1*	32.30±4.7	31.90±4.7	31.23±5.0*	31.32±4.0	30.62±4.2	30.38±4.4*
Muscle strength												
Leg extension (kg)	49.87±2.4	49.91±2.6	49.78±2.6	49.53±4.1	49.83±3.1	49.96±3.1*	49.78±2.5	49.82±2.6	49.94±2.4	49.53±2.4	49.73±2.3	49.90±2.5*
Leg curl (kg)	32.00±2.1	32.18±2.0	31.93±2.3	31.20±1.6	32.33±1.8	33.33±2.5*	32.64±2.1	32.85±2.2	32.87±2.1	32.26±2.0	32.63±2.1	33.10±2.2*
Hand grip (kg)	21.93±2.8	21.87±2.8	21.85±2.7	22.40±2.9	22.47±2.8	22.46±2.7	22.07±2.9	22.45±2.5	23.00±2.8*	21.88±2.8	22.10±2.9	23.46±3.2*
Flexibility (cm)	5.95±1.3	5.96±1.1	5.93±1.9	6.13±1.5	7.26±1.8*$^{+}$	7.88±1.8*$^{+}$	5.90±1.7	6.84±1.4*$^{+}$	7.38±1.4*$^{+}$	6.13±1.1	7.20±1.0*$^{+}$	7.98±1.8*$^{+}$
Vo2Max (Ml/kg/min)	31.62±1.5	31.37±1.2	31.25±1.3	30.86±1.5	31.60±1.5	33.14±1.3*$^{+}$	30.78±1.1	31.42±1.3	32.13±1.7*	30.80±1.4	31.93±1.4	33.16±1.7*$^{+}$
Balance												
Normal stability-eyes open (%)	93.56±2.27	93.58±2.2	93.72±2.7	92.80±1.0	93.10±1.2	94.13±1.0*	92.80±1.5	92.99±1.9	93.12±1.8	92.85±1.4	93.98±1.6*	94.40±1.0*$^{+\#}$
Perturbed stability-Eyes open (%)	92.35±2.6	92.46±2.1	91.90±25	91.89±1.5	91.95±1.7	92.54±1.4*	91.86±3.2	91.90±2.9	92.13±2.9	91.90±3.4	92.16±2.8	93.00±2.9*$^{+}$

* Different from the pretest, significant at the 0.05 level; $^{+}$ Different from the control group, significant at the 0.05 level; $^{\#}$ Different from the RES group, significant at the 0.05 level

Table. 3 Response of biochemical bone marker

	CON (n = 16)		STE (n = 15)		RES (n = 14)		COM (n = 15)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Biochemical bone markers								
β-CrossLaps (ng/ml)	0.330±0.063	0.332±0.071	0.328±0.035	0.349±0.029*	0.331±0.081	0.343±0.075	0.337±0.059	0.352±0.054*
P1NP (ng/ml)	42.86±5.11	42.79±5.74	41.56±2.70	45.28±4.34*	42.21±3.18	43.97±4.26	42.54±2.85	45.71±2.83*
Nmid-osteocalcin (ng/ml)	18.88±0.86	18.76±0.88	18.48±0.89	19.52±1.03*	18.83±0.92	18.93±0.84	18.56±0.89	19.55±0.74*
Bone formation (P1NP)/(βCrossLaps) x 0.31	40.26±3.34	39.95±3.12	39.27±3.12	40.22±3.24*	39.53±2.98	39.73±3.88	39.13±3.45	40.25±2.89*

risks of osteoporosis and falling in women in particular.

This research also finds that three groups of exercises increase muscle mass and muscle strength. However, the COM group shows significant change in balance ability more than the STE and the RES groups. The reason for the better balance ability in the COM group is related to the increased muscle mass and muscle strength for both upper and lower body. This strength increase is most likely caused by the fact that when muscles work harder due to increased stress from increasing the load on the body, there is an increase in motor unit recruitment. Neurotransmission to the muscles thus increases resulting in increased muscle strength. In addition, large axon neuron activation also leads to greater muscle strength[3,14,17]. Overall, the data from the present study have shown that the COM regime is most effective in helping improve balance in the working-age women. This correlates with reports from the studies[1,9,17] on the relationship between muscle strength and balance that show increased muscle strength contributed to increased balance ability. This occurs because each time a person steps up and down; she has to maintain balance and stability, which results in improvement of muscle-control[18]. This, in turn, results in better balance and strength of the thigh muscles in particular as the thighs bear the weight of the body during step aerobics training. In addition, the subjects have to maintain balance while lifting dumbbells during the step aerobics[17,18]. The use of dumbbells increases resistance, making arm and leg muscles stronger than unweighted step aerobics alone[3]. In addition, the stepping motion with added dumbbell resistance helps improve the strength of muscles of the arms, torso, buttocks and legs.

While engaging in the COM exercise regime, the brain translated the data gathered from the environment and position of the body during the exercise. This study shows that the COM regime could improve the participants' balance when their eyes aim to both hard as well as soft surface. This is the time they use visual and other proprioceptive data to stabilize the body. It is believed that this leads to improved awareness of body position caused by increased proprioception in the muscles, tendons and joints from step aerobic exercise[1,9,18]. The impact from the ground and the added weight from the dumbbells sends information about changes in muscles, compression and movements in the various tissues involved to the brain, which responds by recruiting muscles to contract, or relax appropriately[14]. Moreover, improved 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[14]. It works by locating the position of the head, whether vertical or horizontal, and stabilizing it in space. Step aerobic exercise combined with resistance training including the up and down movements makes use of gravity, which helps develop the functioning of the vestibular apparatus. Various studies have shown[10,18] that marked improvement of balance variables from combined aerobic exercise and resistance training as both forms of exercise can improve muscle strength. It can be concluded that when the muscles are stronger, the nervous system functions are better; balance also improves. This can help reduce risk of having fractures from falling on both hard and soft surfaces, which occur commonly in daily life[11,18].

With respect to bone biochemical properties, the study findings correspond to the hypothesis that the COM and STE exercise regime would yield better results than the RES regimes. At week 16 of the program, it was found that bone mass resorption (β-CrossLaps) of the participants in the COM group increased to the normal range for the working-age women. This indicates that the bone remodeling cycle has started. COM and STE are impact exercises and many studies[1,5,7,12] 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[8] and causing the leg muscles to contract more as they try to maintain balance while doing step aerobics. This stimulates activity of bone cells (osteoblasts) and the compression on the bones increases the process of mineralization of the bones[1,16]. Muscle contraction is a major force exerted on the bones. The effects of exercise on the bones is assessed in terms of physical strain such as the weight of the ground against the body standing on it, i.e. ground-reaction force, or muscle contraction forces on a particular area of bone. The bones function like piezoelectric crystal that can produce a small electric charge in a ratio that corresponds to the ground reaction force[7,12]. Mechanical force created by the stepping motion most likely has an effect on the bones, causing microfractures that are not visible[1]. This stimulates osteoclast activity to reabsorb bone tissue and thus increase bone resorption (β-CrossLaps). At the same time, osteoblast activity remodels the bones which increases bone formation (P1NP) which took place in the subjects of the COM and STE exercise regimes in this study. These types of exercise may also cause bone remodeling by stimulating osteocytes which react to the ground reaction force[1]. This results in chemicals from neurotransmitters that act on bone precursor cells to increase bone turnover (Nmid-Osteocalcin) to normal ranges for the working-age women[4]. In this research, CTx was used as the bone resorption marker (β-CrossLaps)[4] which was normal. When bone formation (PINP/β-CrossLaps x0.31)[4] was investigated, the result was that the values increased compared to pre-experiment and control group values ($p<0.05$). This confirms that COM has positive effects on bone formation. This may be because the COM exercise regime made leg muscles contract with more force during step aerobics and from maintaining balance while stepping up and down while the upper body had added resistance from the use of dumbbells. The frequency and intensity of resistance training should cause strain from the continuous contraction of muscles when resisting external force on the muscles, tendons, bones and joints. Numerous studies[3,13,19] indicate marked alterations of bone biochemical substances because of resistance training. Moreover, physiological changes and health-related increases in fitness and balance correlate to positive bone development[8,15,20]. This concurs with the findings of this study that general physiological and body components have resulted in increased bone density[8,20]. It is likely that aerobic exercise improves the respiratory system and blood circulation, which increases stroke volume[21]. This, in turn, causes heart rate to slow making the heart more efficient and able to carry blood with more oxygen to the muscles to meet the added oxygen demand during exercise[21]. This consequently causes the muscles to become stronger and the nervous system to work more efficiently[1,9]. Balance and bone formation have also shown the improvement[1,15].

There were a number of limitations in the present study that should be emphasized. First, 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 the working-age women are at risk of developing osteoporosis, through exercise instead of drug therapy would be a very beneficial alternative eliminating the medication treatment that costs for both individuals as well as the country. Second, to the best of our knowledge, this is the first study to investigate this issue in a southeastern Asian population. There is no scientific reason to speculate that the southeastern Asian people in general and Thai people in particular respond differently to exercise training programs. Nevertheless, the generalizability of the findings may be limited. It can be concluded that the COM exercise regime is appropriate for the working-age women as it can develop physical strength, increase bone mass formation, and improve health-related fitness and balance, so they will be ready to enter the postmenopausal age while minimizing the risk of developing osteoporosis in the future.

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Potential conflicts of interest

None.

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ผลของการฝึกการออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้แรงต้านที่มีผลต่อสารชีวเคมีของกระดูก สุขสมรรถนะและการทรงตัวในสตรีวัยทำงาน

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วัตถุประสงค์: *เพื่อพัฒนาโปรแกรมการออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้แรงต้านและศึกษาเปรียบเทียบผลของการฝึกการออกกำลังกายระหว่างการออกกำลังกายสเตปแอโรบิค การออกกำลังกายแบบใช้แรงต้าน และการออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้แรงต้านที่มีผลต่อการสร้างมวลกระดูก การสลายมวลกระดูก สุขสมรรถนะ และการทรงตัวในสตรีวัยทำงาน*

วัสดุและวิธีการ: *อาสาสมัครซึ่งเป็นสตรีวัยทำงานที่มีอายุระหว่าง 35-45 ปี และเป็นบุคลากรภายในจุฬาลงกรณ์มหาวิทยาลัยจำนวน 72 คน มีการเลือกกลุ่มตัวอย่างด้วยวิธีสุ่มอย่างง่ายโดยแบ่งออกเป็น 4 กลุ่มๆ ละ 18 คน ภายหลังการทดลอง 16 สัปดาห์ กลุ่มตัวอย่างมีจำนวน 60 โดยแบ่งออกเป็นกลุ่มการฝึกออกกำลังกายสเตปแอโรบิค 15 คน กลุ่มออกกำลังกายแบบใช้แรงต้าน 14 คน กลุ่มออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้แรงต้าน 15 คน และกลุ่มควบคุม 16 คน โดยรูปแบบการฝึกการออกกำลังกายทั้ง 3 รูปแบบนั้นได้ผ่านตรวจสอบ ค่าความตรงโดยผู้เชี่ยวชาญ 5 คนและผ่านการตรวจสอบความเที่ยงแบบวัดซ้ำของอัตราการเต้นหัวใจขณะฝึกการออกกำลังกายก่อนที่จะทำการฝึกทดลอง ทั้งนี้ได้มีการศึกษานำร่องก่อนจะนำมาใช้ฝึกจริงเพื่อหาความสัมพันธ์ระหว่างความหนักของโปรแกรมจากอัตราการเต้นของหัวใจ และจังหวะดนตรีที่ใช้เพื่อจะทำให้ทั้ง 3 กลุ่ม ออกกำลังกายได้ฝึกในความหนักของโปรแกรมการฝึกในอัตราการเต้นของหัวใจช่วงเดียวกันในแต่ละระยะการฝึก โดยคำนึงถึงความสูงของสเตปและความหนักของดัมเบลที่นำมาประกอบการฝึกก่อนลงมือการฝึกทดลองทั้ง 3 รูปแบบการออกกำลังกายจะมีการอบอุ่นร่างกายก่อนการฝึกและคลายอุ่นหลังการฝึกพร้อมกับการยืดเหยียดกล้ามเนื้อเป็นเวลา 5 นาที และได้แบ่งระยะการฝึกออกเป็น 3 ระยะคือ ระยะที่ 1 ในช่วง 2 สัปดาห์แรก ผู้เข้าร่วมวิจัยจะฝึกโดยใช้โปรแกรมการเตรียมพร้อมร่างกายออกกำลังกายที่ระดับความหนัก 50-59% ของอัตราการเต้นหัวใจสูงสุด ระยะที่ 2 ในช่วงสัปดาห์ที่ 3-8 ได้เพิ่มความหนักของโปรแกรมเป็น 60-69% ของอัตราการเต้นหัวใจสูงสุด, ระยะที่ 3 ในช่วงสัปดาห์ที่ 8-16 ได้เพิ่มความหนักของโปรแกรมเป็น 70-80% ของอัตราการเต้นหัวใจสูงสุด โดยกลุ่มควบคุมใช้ชีวิตประจำวันตามปกติ แล้วดำเนินการเก็บข้อมูลทั้งก่อนการทดลอง หลังการทดลอง 8 สัปดาห์ และหลังการทดลอง 16 สัปดาห์ คือทดสอบทางสรีรวิทยาทั่วไป สารชีวเคมีของกระดูก สุขสมรรถนะทางกายและความสามารถในการทรงตัว โดยมีระยะเวลาการทดลองเป็นเวลานาน 16 สัปดาห์ๆ ละ 3 วัน*

ผลการศึกษา: *ภายหลังการฝึก 16 สัปดาห์ พบว่าค่าการสร้างมวลกระดูก ค่าบีตาครอสแล็ปส์ ค่าพีวันเอ็นพี และค่าเอ็นมิดออสทีโอแคลซินในกลุ่มออกกำลังกายสเตปแอโรบิคและกลุ่มออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้แรงต้านมีค่าเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ เมื่อเทียบกับก่อนการทดลองแต่ไม่พบการเปลี่ยนแปลงอย่างมีนัยสำคัญทางสถิติของสารชีวเคมีกระดูกในกลุ่มออกกำลังกายแบบใช้แรงต้าน สำหรับค่าความสามารถในการทรงตัวในกลุ่มการฝึกออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้น้ำหนักแรงต้านมีค่าเพิ่มขึ้นอย่างมีนัยสำคัญ เมื่อเทียบกับก่อนการทดลอง กลุ่มควบคุมและกลุ่มการฝึกแบบใช้แรงต้าน*

สรุป: *จากผลการวิจัยสรุปได้ว่ากลุ่มฝึกออกกำลังกายสเตปแอโรบิคผสมผสานกับการใช้แรงต้านและการออกกำลังกายแบบสเตปแอโรบิคมีผลดีต่อค่าการสร้างกระดูกแต่ไม่พบการเปลี่ยนแปลงของการสร้างกระดูกในกลุ่มออกกำลังกายแบบใช้แรงต้าน ทั้งนี้การออกกำลังกายสเตปแอโรบิค*

ผสมผสานกับการใช้แรงต้าน ส่งผลดีในด้านการทรงตัวในสตรีวัยทำงานมากกว่าการฝึกการออกกำลังกายแบบใช้แรงต้านเพียงอย่างเดียวอย่างมีนัยสำคัญทางสถิติ ซึ่งส่งผลให้ช่วยลดอุบัติการณ์กระดูกหักจากการหกล้มได้
