Effects of Two Modes of Exercise on Physical Fitness and Endothelial Function in the Elderly: Exercise with a Flexible Stick Versus Tai Chi

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Objective: *Determine the effects of exercise with flexible stick training on physical fitness and endothelial function and compare it with Tai Chi training.*
Material and Method: *Thirty older women volunteered for the present study and were divided into EF group (EF: n = 16; 70.3 $\pm$ 2.5 yr) and TC group (TC: n = 14; 69.5 $\pm$ 4.5 yr). Both training groups performed training assigned protocol that consisted of 70% of maximal heart rate, 40 minutes per day, four days per week for 12 weeks. Health related physical fitness and biochemical data were assessed in all participants. Post-Occlusive Reactive Hyperemia (PORH) was used to monitor endothelial function by using a Laser-Doppler fluxmeter.*
Result: *The health related physical fitness was significantly higher in the EF group ($p < 0.05$). Plasma malondialdehyde and von Willebrand factor, an indicator of free radical damage and endothelial dysfunction, respectively as well as cholesterol level were significantly lower ($p < 0.05$) in the EF group. The peak Laser-Doppler flux (LDF)/baseline LDF, and recovery time were significantly improved after 12 weeks of EF training ($p < 0.05$). This was not observed after 12 weeks of TC training.*
Conclusion: *EF, a Thai novel exercise that combined endurance and strength training was a more effective exercise modality than TC for improving physical fitness and endothelial function. It improved reactive oxygen species in the elderly.*

Keywords: *Exercise with a flexible stick, Tai Chi, Health related physical fitness, Postocclusive reactive hyperemia, Reactive oxygen species*

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Aging is an independent risk factor for hypertension, atherosclerosis, and coronary heart disease. It has been hypothesized that vascular dysfunction precedes these pathological diseases and could contribute to their progression(1). Accordingly, age-related reductions in endothelium-dependent vasodilatation have been observed(2,3). Reactive oxygen species and the concomitant oxidative stress may play an important role in the process of endothelial aging(4). Some investigations have revealed that regular exercise diminishes age-related endothelial dysfunction(5-7).

Regular aerobic exercise and strength training are frequently prescribed for the prevention and treatment of cardiovascular disease and frailty associated with aging(8). Aerobic endurance training can increase oxygen transport and consumption capacities whereas resistance training has a significant effect on muscle mass and force(9). Previous studies have shown that a long-term combined aerobic and strength-training program is more effective than an aerobic training program alone in producing changes in body composition of males with coronary artery disease (CAD)(10). Moreover, the addition of resistance exercise appears to enhance the total fitness profile by improving muscular performance, muscle morphology,

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and cardiovascular fitness more than performing aerobic exercise alone[11].

Although combined aerobic and resistance training is recommended as an integral component of an overall cardiorespiratory and muscular fitness program, studies that have examined the effects of the simultaneously combined endurance and resistance trainings are limited. Recently, it was found that regular rowing exercise, a combination of endurance and strength training during the usual training regimen, is associated with a favorable effect on elastic properties of central arteries in middle aged and older adults[8]. However, no previous studies have examined the effect of combined aerobic with resistance exercise on microcirculation, especially among the elderly. Therefore, the inclusion of both exercise modalities to an exercise program should be developed.

Tai Chi (TC) is a traditional Chinese martial art. It combines deep diaphragmatic breathing and relaxation with many fundamental postures that flow imperceptibly and smoothly from one to the other through slow, gentle, and graceful movements[12]. A previous study indicated that TC is a moderate intensity, aerobic exercise[7]. Recent studies corroborate its benefits in cardiorespiratory function, muscle strength, and posture control[13,14]. TC is also thought to improve psychological conditions such as anxiety and depression and is wildly practiced in many countries as a form of exercise for health and fitness. However, TC is complicated to learn. For newcomers, trying to learn TC may intimidate and discourage the more senior practitioners, lower their self-esteem, diminish their interest, and decrease their participation rate[15].

In this regard, "Exercise with a Flexible stick" (EF), the Thai exercise model innovation is unique, as it combines aerobic endurance with a muscular strength exercise program constructed by Suksom D et al[16], which won the first prize in Thailand's Exercise Innovation Award in 2005. The flexible stick, made by two bamboo sticks and two rubber-string loops, was created as the exercise equipment for increasing load integrated with aerobic exercise (Fig. 1). The EF model was intended for the elderly to promote continuous motion of the major muscle groups by incorporating elements of Thai culture such as Thai dance and Ram krabi-krabong movement, which are compatible with Thai musical instruments. EF is an easy-to-learn and perform exercise program, which is suitable for the sedentary elderly population.

Accordingly, the purpose of the present study was to determine the effects of EF training in comparison with TC training on health-related physical fitness and endothelial function in the elderly. It was hypothesized that greater health benefits in the elderly could be gained from EF training compared with the TC training.

Material and Method

Subjects

Thirty older women in Dindaeng Services Center for the Elderly, Bangkok, Thailand volunteered for the study and were randomly assigned into the EF group and the TC group. Their medical and activity backgrounds were obtained through a questionnaire. Subjects who displayed a history of hypertension (systolic > 160 mmHg, diastolic > 100 mmHg), cardiovascular diseases or chronic diseases *i.e.* atherosclerosis, diabetes, rheumatoid arthritis were excluded. All subjects gave written informed consent. This investigation was approved by The Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University.

Exercise with a flexible stick (EF) training protocol

EF comprises 83 postures assumed over a 40 minutes/session. The format of the EF training session included 13 postures for the warm-up period (5 minutes), 57 postures for the stimulus period (30 minutes), and 13 postures for the cool-down period (5 minutes)[15]. The EF instructor led the EF practice and all subjects imitated each posture according to her. The subjects practiced EF nearly every day in the early morning, four times per week for 12 weeks.

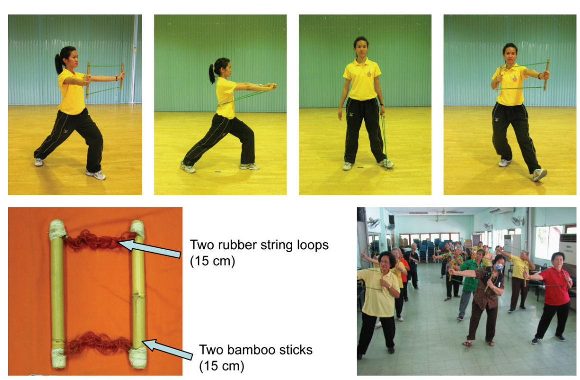

Fig. 1 Exercise with a flexible stick (EF) model

Tai Chi (TC) training protocol

The subjects practiced a simplified, 24-form TC by following instructions provided by a qualified trainer. Each session of TC included five minutes warm-up, 30 minutes of TC practice, and five minutes of cool-down exercise. During the TC session, subjects were led by a Tai Chi instructor and imitated the motions and postures at the same speed as the instructor. The subjects participated in the TC training program four times per week for 12 weeks.

General characteristics and health-related physical fitness

The physical and physiological characteristics of subjects such as height, body weight, body mass index (BMI), resting heart rate and blood pressure were assessed before and after 12 weeks of exercise training. Body weight, resting heart rate and blood pressure were measured using an analogue weight scale (Tanita UM-052, Japan), heart rate monitor (Polar Electro S810, Finland), and mercury sphygmomanometer (Spirit, UK), respectively. The percent body fat was measured by whole body bioelectrical analysis (BIA) analyzer (Maltron, England)[17]. The flexibility, shoulder flexion/ shoulder abduction/ hip flexion/ hip abduction range of motion, were also measured by Goniometer (Jama, Japan)[18]. The dynamic strength of the biceps, triceps, quadriceps and hamstrings muscle of the subjects was assessed by one-repetition maximum (1 RM) in the biceps curl, triceps extension, leg press and leg curl, respectively, by using the standard weight machine (Marathon, Thailand). Briefly, weights were chosen so that 1 RM could be determined in three to five attempts. Maximum weight lifted was recorded as the greatest amount of weight successfully lifted one time. Verbal encouragement was given to each subject during the 1 RM test[19]. The modified Bruce treadmill protocol was used for the VO_2 max measurement. Subjects were asked to run on a treadmill (Landice, USA), in which the grade and intensity were increased every three minutes until exhaustion. Oxygen consumption, carbon dioxide expiration, minute ventilation, and blood pressure were measured throughout the test using a breath-by-breath gas analysis system (Cortex metamax 3B, Germany). The VO_2max was determined by using at least two of the following criteria: VO_2max increased less than 2 ml/kg/min after at least two minutes, Heart rate (HR) exceeded its predicted maximum, or the respiratory exchange ratio (RER) exceeded 1.15[7]. Heart rate (HR) was recorded using a heart rate monitor (Polar Electro S810, Finland).

Blood chemistry analysis

Blood samples were taken, pre- and post-exercise training program, and were obtained from an antecubital vein. Whole blood was then centrifuged at 1200g for 20 min at 4°C and serum was stored at -70°C until analysis. Lipid profiles including total cholesterol (CHOL), triglycerides (TG), high density lipoprotein cholesterol (HDL-C) and low density lipoprotein cholesterol (LDL-C), and von Willebrand factor (vWF) were analyzed from whole blood, using the colorimetric method (Bangkok RIA lab CO., LTD). The serum malondialdehyde (MDA) level was determined using thiobarbituric acid reaction as described by Ohgawa et al, 1979[20].

Post-occlusive reactive hyperemia

Post-Occlusive Reactive Hyperemia (PORH) is a temporary increase in blood flow after the release of a temporary occlusion of arterial inflow. PORH was used as an index of endothelial function[21]. After the subjects rested quietly in the supine position for 15-20 minutes, they were instrumented with Laser-Doppler fluxmetry probes (DRT4 laser Doppler Perfusion and Temperature Monitor, Moor Instruments), which measured an index of skin blood flow (flux). The Laser-Doppler Flux (LDF) reading reflected only SkBF and was not influenced by underlying muscle blood flow[22]. After a 5-minute basal LDF recording, a cuff was placed on the upper arm, proximal to the Doppler probes, the ventral part of forearm and inflated to a suprasystolic pressure (200 mmHg) for five minutes. After sudden release of the cuff, the peak hyperemia response (peak LDF) and the duration of hyperemia (recovery time) for five minutes were recorded. The blood flow data were expressed in arbitrary perfusion units (PU) and the digitalized LDF signal was simultaneously transmitted to a personal computer for further analysis.

Statistical analysis

Data were expressed as mean $\pm$ standard deviation. SPSS version 11 for Windows statistical software was used to analyze the data. The differences of various parameters between pre- and post-test exercise training were analyzed by paired t-test. The differences of the change after training of various parameters between EF and TC group were analyzed by unpaired t-test. One-way analysis of variance, followed by Tukey's multiple comparison was used to determine the significant differences among groups of subjects. Differences were considered significant at $p < 0.05$.

Results

General characteristics and health related physical fitness data

The general characteristics and health related physical fitness data of subjects are summarized in Table 1. There were no significant differences in weight, height, and body mass index between EF and TC before and after 12 weeks training. After 12 weeks of EF and TC training, resting heart rates were significantly lower as compared with pre-exercise training ($p < 0.05$). The percent body fat, lean body mass, and systolic blood pressure was lower at the post-test ($p < 0.05$) EF training. Furthermore, the post-test of the EF training group exhibited a significantly higher value for 1 RM of the biceps, triceps, quadriceps and hamstrings muscles and VO_2max as compared with the pre-test ($p < 0.05$). No such findings were observed in the TC group. Moreover, the change after 12 weeks training of VO_2max in EF group was significantly higher than those of the TC group.

Blood chemical data

Blood chemical data are shown in Table 2. The results demonstrate that CHOL levels were significantly decreased after 12 weeks of EF training ($p < 0.05$). However, there were no significant differences in other cholesterol parameters including TG, HDL-C and LDL-C in both EF and TC groups when comparing pre- and post-training values. Interestingly, serum malondialdehyde (MDA) and the percentage of von Willerbrand factor (vWF) levels of the post- EF training were found to be significantly lower ($p < 0.05$) compared with the pre- EF training, but not after TC training.

Post occlusive reactive hyperemia (PORH) data

The release of the cuff after 5-minute occlusion induced a transient increase in LDF, which is consistent with the characteristic of hyperemic response. The baseline LDF and Peak LDF showed no significant difference between pre- and post-training in both EF and TC groups. However, significantly higher ($p < 0.05$) values were found in the peak LDF/baseline, LDF and recovery time only after EF training (Table 3).

Discussion

Exercise with a Flexible stick (EF) was created for enhancing cardiovascular fitness while simultaneously promoting muscular strength. To determine the beneficial effects of EF training for the elderly, the investigators measured health-related

Table 1. General characteristics and health-related physical fitness data

Variables	EF (n = 16)			TC (n = 14)		
	Pre test	Post test	Change from pre test	Pre test	Post test	Change from pre test
Age (years)	70.3 ± 2.5			69.5 ± 6.5		
Height (cm)	150.8 ± 4.6	150.7 ± 4.5		153.4 ± 4.2	152.1 ± 5.6	
Body weight (kg)	58.9 ± 6.9	58.3 ± 7.2	-0.4	58.6 ± 12.2	58.7 ± 12.6	0.1
Resting HR (beat/min)	73.8 ± 16.5	69.0 ± 14.9*	-3.2	72.7 ± 12.8	68.8 ± 6.0*	-3.9
Systolic BP (mmHg)	134.0 ± 16.4	124.8 ± 17.6*	-6.9	134.2 ± 16.3	127.5 ± 18.1	-6.7
Diastolic BP (mmHg)	71.9 ± 8.6	66.6 ± 8.2	-4.5	77.2 ± 10.7	71.4 ± 8.4	-5.8
BMI (kg/m^2)	26.5 ± 3.1	26.0 ± 3.3	-1.9	25.0 ± 4.1	24.4 ± 3.6	1.1
Body fat (%)	36.1 ± 6.2	34.58 ± 5.8*	-3.1	33.76 ± 7.9	33.8 ± 8.9	0.0
Lean body mass (%)	61.3 ± 5.3	67.9 ± 3.5*	4.1	64.2 ± 8.1	70.6 ± 4.9*	6.6
1 RM-Biceps (kg)	4.4 ± 1.8	6.8 ± 1.4*	2.6	4.7 ± 1.1	5.7 ± 1.3	1.0
1 RM-Triceps (kg)	10.4 ± 1.6	13.8 ± 1.6*	2.5	11.7 ± 2.1	12.3 ± 3.5	1.6
1 RM-Quadriceps (kg)	9.0 ± 2.0	10.4 ± 1.7*	1.2	8.2 ± 4.7	10.0 ± 2.0*	2.1
1 RM-Hamstrings (kg)	14.4 ± 3.9	17.9 ± 3.6*	3.8	16.4 ± 5.9	18.69 ± 5.3*	2.3
VO_2max (ml/kg/min)	17.3 ± 2.4	23.6 ± 2.3*	9.4	19.9 ± 3.5	20.7 ± 4.1	2.8^+

Values are means ± SD

* $p < 0.05$, pre test versus post test in the same group

$^+$ $p < 0.05$, change from pre test of EF group versus change from pre test of TC group

EF = exercise training with flexible stick; TC = Tai Chi training; HR = heart rate; BP = blood pressure; BMI = body mass index, 1RM = one-repetition maximum, VO_2max = maximal oxygen consumption

Table 2. Blood biochemical data

Variables	EF (n = 16)			TC (n = 14)		
	Pre test	Post test	Change from pre test	Pre test	Post test	Change from pre test
Hb (mg/dl)	12.7 ± 1.1	12.8 ± 1.2	0.5	13.3 ± 1.1	12.6 ± 1.1	-0.8
Hct (%)	39.5 ± 3.4	39.1 ± 2.8	-0.8	41.5 ± 3.7	38.6 ± 2.5	-1.6
CHOL (mg/dl)	226.0 ± 36.6	201.7 ± 31.9*	-18.6	214.7 ± 43.4	204.6 ± 38.3	-10.2
TG (mg/dl)	120.4 ± 79.5	120.6 ± 58.5	0.4	118.0 ± 38.0	138.1 ± 73.9	8.4
HDL-C (mg/dl)	66.8 ± 12.0	65.9 ± 10.1	-2.7	64.0 ± 35.9	63.6 ± 13.1	-3.1
LDL-C (mg/dl)	130.7 ± 37.1	131.0 ± 33.2	0.2	132.81 ± 46.32	136.0 ± 40.0	1.5
MDA (nmol/ml)	6.1 ± 1.6	4.6 ± 1.1*	-3.4	6.5 ± 1.5	5.6 ± 1.5	-1.1
vWF (%)	146.0 ± 27.8	135.2 ± 26.6*	-8.3	145.9 ± 32.9	140.5 ± 32.4	-3.8

Values are means ± SD
* $p < 0.05$, pre test versus post test in the same group
EF = exercise training with flexible stick; TC = Tai Chi training; Hb = hemoglobin; Hct = hematocrit; CHOL = total cholesterol; TG = triglyceride; HDL-C = high density lipoprotein cholesterol; LDL-C = low density lipoprotein cholesterol; MDA = malondialdehyde; vWF = Von Willebrand factor

Table 3. Indices of post occlusive reactive hyperemia (PORH)

Variables	EF (n = 16)			TC (n = 14)		
	Pre test	Post test	Change from pre test	Pre test	Post test	Change from pre test
Baseline LDF (PU)	20.30 ± 11.75	15.19 ± 5.42	-2.9	19.31 ± 8.96	18.18 ± 9.14	-0.7
Occluded LDF (PU)	5.20 ± 4.53	3.60 ± 0.59	-2.1	3.42 ± 0.60	3.57 ± 0.65	0.2
Peak LDF (PU)	71.97 ± 14.25	79.95 ± 15.56	4.5	67.54 ± 15.64	72.76 ± 16.32	0.8
Peak LDF/ baseline LDF (PU)	4.52 ± 1.42	5.23 ± 1.90*	1.2	4.38 ± 2.36	4.60 ± 2.24	0.4
Recovery time (sec)	188.21 ± 22.56	172.15 ± 21.24*	-12.8	185.48 ± 24.38	179.64 ± 22.21	-5.7

Values are means ± SD
* $p < 0.05$, pre test versus post test in the same group
EF = exercise training with flexible stick; TC = Tai Chi training; LDF = laser Doppler flux, PU = perfusion units

physical fitness and endothelial function of older women before and after 12 weeks of EF training and compared these with a group receiving TC training, a traditional Chinese conditioning exercise that includes slow, smooth and harmonic movement. In the present study, the older women participated in either EF or TC training for 40 minutes of continuous movement, 4 days/week for 12 weeks. The average oxygen costs for EF and TC were 14.50 ml/kg/min and 12.75 ml/kg/min, respectively, which were identified as moderate-intensity exercise according to the five-level classification of physical activity based on exercise intensity[23]. The results indicated that 12 weeks of EF training can improve health-related physical fitness by decreasing the percent body fat and increasing upper and lower muscular strength, flexibility and cardiorespiratory fitness, as well as improve endothelial function by increasing cutaneous microcirculatory responsiveness and decreasing vWF level. These changes were accompanied by a decreased MDA level. By contrast, participants in the TC training showed improvement only in lower muscular strength and flexibility.

Although the older subjects were still physically active, their baseline systolic blood pressures were abnormally high to the borderline.

However, those values showed a significant decrease after the EF training protocol. Thus, the decreases in blood pressure observed in the present study are suggestive of a beneficial health effect of the combined aerobic and resistance-exercise training program. At the end of the training period, the body weight of the subjects was not significantly affected whereas the percent body fat decreased significantly only in the EF group. EF training can significantly prevent lipid abnormalities as demonstrated by lowering the plasma cholesterol level. Because a high plasma lipid level has been associated with cardiovascular disease[24], it is conceivable that EF might be a new exercise training that had beneficial effects for preventing cardiovascular disease in aging.

In the present study, the researchers found that both EF and TC resulted in increased leg muscular strength in aging. The reason for this finding is unclear but it could be that EF and TC put equal emphasis on the exact joint position and limb direction. TC involved precisely controlled weight shifting between a double-leg stance and a single-leg stance, in a smooth and coordinated manner[14]. By contrast, the EF movements imitated those of Thai classical dance and Ram krabi-krabong movement, which were the principle of body movements concerning the reciprocal relation between body weight transfer and limb rotation. This exercise consisted of gentle and slow movements with short steps controlled by, and in rhythm to, the accompanying traditional Thai music. The gain in strength of the upper body muscles was higher in the EF training group; no gain was observed in the TC training group. This may be due to the use of resistance load on the upper body using the flexible stick during EF. This finding was consistent with a previous study reported by Verney J, et al[25]. They indicated that the combination of lower body endurance and upper body resistance training could improve maximal isometric and isokinetic torque during shoulder abduction associated with a significant increase in deltoid, pectoralis major, pectoralis minor, piriformis, psoas major, subscapularis and trapezius muscles in a cross-sectional area. Taken together, these data suggest that, for the elderly, increasing upper muscular strength is important to achieving effectiveness of daily physical activity.

Although the EF and TC exercise training programs could induce physical adaptation to training as indicated by a decrease in resting heart rate, only the older members of the EF group displayed greater VO_2max. The lack of favorable effects of TC in cardiorespiratory function in the current study is consistent with a previous meta-analysis conducted by Lee MS, et al[13] who examined the effect of Tai Chi on aerobic capacity and reported that the existing evidence did not suggest that regular Tai Chi was an effective way of increasing aerobic capacity. They also reported that a meta-analysis of data from three randomized clinical trials failed to show an effect of Tai Chi on aerobic capacity compared with sedentary controls. Moreover, the results of two randomized clinical trials showed that Tai Chi was not statistically significantly superior to general physical exercise such as brisk, low-intensity, and moderate-intensity walking, and aerobic exercise. By contrast, Taylor-Piliae RE[26] reported that, from a total of 170 citations, large significant effects of Tai Chi on aerobic capacity were found for subjects enrolled in the cross-sectional studies (ES = 1.33), in both women and men, among adults ≥ 55 years old, and when compared to sedentary subjects. Nevertheless, only non-significantly small to moderate effects, were found in subjects enrolled in the experimental studies (ES = 0.38), adults < 55 years old, when comparing subjects participating in other physical activity with those in the Tai Chi exercise groups. Those studies suggested that Tai Chi was only effective in improving aerobic capacity when practiced over a long period of time. Thus, Tai Chi training for 12 weeks in the present study might not be long enough to improve cardiorespiratory function. In the current study, the improvement in health-related fitness after EF training is consistent with previous studies that determined the effect of combined aerobic and resistance training in healthy subjects[8,11] and in patients with coronary artery disease[27] as well as in heart failure patients[28]. The data show that older women who regularly performed EF exhibited higher energy expenditure, probably through using the upper and lower body, utilizing both limbs simultaneously to generate a powerful force resulting in cardiovascular function. Thus, the authors suggest that the additional resistance load to aerobic exercise movement could be more effective in improving cardiovascular fitness for elderly persons who have slow movement and limitations in balance and mobility.

It has been shown that endothelial function is impaired in the elderly[29] and Reactive oxygen species (ROS) was suggested to play an important role in the process of endothelial aging[4]. A previous study demonstrated that aging is associated with a decline in cutaneous microcirculatory responsiveness[7], impaired skin vessel reactivity to an endothelium-dependent vasodilator[30] and smaller increases in skin-blood flow for a given rise in body temperature[31]. This is partly caused by a decrease in sympathetic active vasodilator sensitivity rather than an increase in a sympathetic vasoconstrictor[32]. Several investigators have shown that aerobic exercise is an effective intervention to improve endothelial dysfunction in a variety of populations[33-35] including in the elderly[7,22]. In addition, it has been previously demonstrated that resistance training improves peripheral artery endothelial function, measured by flow-mediated dilation of the brachial artery, in overweight women[36]. However, the benefit of combining aerobic with resistance exercise on vascular function has not been well-established. To date, only one previous study[8] has examined the effects of rowing, a combination of endurance and strength training during the usual training regimen, on arterial elasticity. The investigators found that habitual rowers demonstrated a greater central arterial compliance and higher cardiovagal baroreflex sensitivity than sedentary controls that were matched for many potentially confounding factors. These findings suggest that concurrently-performed endurance training may negate the stiffening effects of resistance training on arterial compliance since resistance training was associated with lower, rather than higher, central arterial compliance[37].

Post-occlusive reactive hyperemia, mediated mainly by endothelium-dependent factors, can be as suitable, measured by laser-Doppler flowmetry, for the assessment of endothelium-dependent vasodilation at the level of capillaries and arterioles[38]. In the present study, to assess cutaneous vascular responsiveness, the researchers performed an artery occlusion and determined the parameters of PORH, which was considered an appropriate measure of endothelium-dependent flow-induced vasodilation, to indicate endothelial function[21]. The results show that endothelial function was impaired in the elderly when compared with younger subjects. Additionally, the present study revealed that older women who regularly performed EF exhibited greater peak LDF/baseline LDF, time to peak LDF and recovery time as well as lower levels of vWF, an indicator of endothelial dysfunction. No such effect was found in subjects who performed TC. Therefore, the authors suggest that EF training was sufficient to improve endothelial function. One reason that EF but not TC could improve endothelial function in the elderly may be the fact that combining aerobic with resistance training was more effective in attenuating ROS, or that aging-impaired endothelial function was great enough to overwhelm the protective effects of TC training. According to previous observations, this finding could also be due to an increased production of nitric oxide (NO) as a consequence of shear stress induced by regular exercise training that led to an increase in eNOS activity of protein and eNOS gene expression[39,40]. Moreover, ROS has been well-documented for its involvement in mediating endothelial dysfunction by inactivation of NO[33,41]. In the current study, the results indicate that serum MDA levels of the older women were significantly lower after 12 weeks of EF training. As a result, the authors speculate that EF training conferred beneficial effects to ameliorate the harmfulness of oxidative stress in aging. Since the accrual of macromolecular damage induced by ROS is the central causal factor promoting the aging process[42], a regular EF exercise program could provide more benefit to the elderly to reverse the deleterious effects of ROS. Collectively, the diminished values of ROS by EF training in the present study could be related to an enhancement of endothelial function in aging. Increased MDA production can be prevented by EF training due in part to a decrease of lipids the main source of ROS[43], or due to an increase in antioxidant activity therefore facilitating the removal of reactive oxygen substances[44].

Although, in the present study, VO_2max and endothelial function did not improve significantly in the TC group, it cannot be concluded that TC is not suitable for the elderly. Other health-related outcomes of TC training such as balance-control, fall-prevention and psychological effects were not investigated in the present study.

Limitations of the present study are as follows:

1. The number of participants in the present study was small.
2. The participants lifestyles were not closely monitored, which could have some external variations that would affect the result of the study.
3. The present study has not evaluated the appropriateness of intensity that occurred in each exercise pattern.

Therefore, further study needs to determine the appropriateness of flexibility stick equipment and validate the intensity of exercise pattern in order to increase energy expenditure in overweight individuals.

Conclusion

Aging is associated with a decline in physical fitness and cutaneous microcirculatory responsiveness that contribute to age-related cardiovascular disease. The results of the present study show that both regular EF and TC training of the same duration per session (30 minutes) had a favorable effect in promoting health-related physical fitness. However, EF, the Thai innovation of an aerobic-plus-resistance exercise model, was more effective than TC for improving upper-body muscular strength and cardiorespiratory fitness as well as aging endothelial function. Therefore, it is reasonable to conclude that EF training is a suitable exercise to minimize the occurrence of health problems related to aging, because it employs appropriate technology and can be implemented in the community at relatively low cost.

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Potential conflict of interest

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ผลของการฝึกออกกำลังกายสองรูปแบบที่มีต่อสมรรถภาพทางกายและหน้าที่ของเซลล์บุผนังหลอดเลือดในผู้สูงอายุ: การเปรียบเทียบระหว่างการออกกำลังกายด้วยไม้ยืดหยุ่นกับไทชิ

ดรุณวรรณ สุขสม, อาพรรณชนิต ศิริแพทย์ พัทธวรรณ ละโป้, สุทธิลักษณ์ ปทุมราช

วัตถุประสงค์: *เพื่อศึกษาผลของรูปแบบการออกกำลังกายด้วยไม้ยืดหยุ่นที่มีต่อสมรรถภาพทางกาย และหน้าที่ของเซลล์บุผนังหลอดเลือดโดยเปรียบเทียบกับไทชิ*

วัสดุและวิธีการ: *อาสาสมัครเป็นผู้สูงอายุเพศหญิง จำนวน 30 คน แบ่งเป็น 2 กลุ่ม ได้แก่ กลุ่มออกกำลังกายด้วยไม้ยืดหยุ่น (จำนวน 16 คน อายุ 70.3 ± 2.5 ปี) และกลุ่มไทชิ (จำนวน 14 คน อายุ 69.5 ± 4.5 ปี) ทั้งสองกลุ่มได้รับการฝึกออกกำลังกายที่ความหนัก 70 เปอร์เซ็นต์ ของอัตราการเต้นหัวใจสูงสุด วันละ 40 นาที 4 วันต่อสัปดาห์ เป็นเวลา 12 สัปดาห์ ก่อนและหลังการได้รับโปรแกรมฝึกออกกำลังกายอาสาสมัครทุกคนได้รับการทดสอบสมรรถภาพทางกายเกี่ยวกับสุขภาพ และเก็บตัวอย่างเลือดเพื่อวิเคราะห์สารชีวเคมี รวมถึงประเมินหน้าที่ของเซลล์บุผนังหลอดเลือดด้วยวิธีวัดการไหลของเลือดชั้นคิวทาเนียส หลังปิดกั้นการไหลด้วยเครื่องเลเซอร์ดอปเลอร์*

ผลการศึกษา: *พบว่ากลุ่มออกกำลังกายด้วยไม้ยืดหยุ่นมีสมรรถภาพทางกาย เกี่ยวกับสุขภาพที่ดีขึ้นอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 อีกทั้งมาลอนไดอัลดีไฮด์ในพลาสมา ซึ่งเป็นตัวบ่งชี้การทำลายของอนุมูลอิสระวอนวิลเลแบรนด์แฟฃเตอร์ในพลาสมา ซึ่งเป็นตัวบ่งชี้การสูญเสียหน้าที่ของเซลล์บุผนังหลอดเลือด และไขมันคอเลสเตอรอลของกลุ่มออกกำลังกายด้วยไม้ยืดหยุ่น มีระดับต่ำลงอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 แต่ไม่พบการเปลี่ยนแปลงของค่าดังกล่าวในกลุ่มไทชิ นอกจากนี้ ค่าการไหลของเลือดชั้นคิวทาเนียสสูงสุด/การไหลของเลือดชั้นคิวทาเนียสขณะพัก และค่าระยะเวลาการฟื้นตัวของการไหลของกลุ่มออกกำลังกายด้วยไม้ยืดหยุ่นมีค่าดีขึ้นภายหลังการฝึก 12 สัปดาห์ ในขณะที่กลุ่มไทชิ ไม่พบการเปลี่ยนแปลง*

สรุป: *ผลการวิจัยชี้ให้เห็นว่าการออกกำลังกายด้วยไม้ยืดหยุ่น ซึ่งเป็นรูปแบบการออกกำลังกายใหม่ของไทยที่เป็นการออกกำลังกายแบบแอโรบิกผสมผสานกับการออกกำลังกายแบบใช้แรงต้านในการออกกำลังกาย ครั้งเดียวมีผลในการเสริมสร้างสมรรถภาพทางกาย และหน้าที่ของเซลล์บุผนังหลอดเลือดได้อย่าง มีประสิทธิภาพมากกว่าไทชิ โดยเป็นผลจากการที่สามารถช่วยให้อนุมูลอิสระลดลงได้ในผู้สูงอายุ*