Original Article

Effects of Arm Swing Exercise Training on Cardiac Autonomic Functions in Response to Incremental Exercise in Overweight and Normal Weight Young Adults

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Background: Excess weight is associated with cardiac autonomic dysfunction at rest and during exercise. Exercise training has been proven to be effective for restoring cardiac autonomic function.

Objective: To evaluate the effect of arm swing exercise (ASE) training on cardiac autonomic function in response to incremental exercise in overweight young adults.

Materials and Methods: Forty sedentary young adults were classified into overweight and normal weight groups in accordance with age and sex. All subjects took part in an ASE training program for 2 months, 30 minutes/day, 3 days/week. Before and after the training, subjects' cardiac autonomic function was evaluated via heart rate variability analysis throughout the incremental exercise as well as during recovery.

Results: Prior to ASE training, during low-intensity exercise, mean heart rate (HR) in the overweight group was higher than that in the normal weight group ($p<0.05$). However, during high-intensity exercise, mean HR and the longitudinal diameters of the Poincaré plot (SD2) value in the overweight group were lower than those in the normal weight group ($p<0.05$). These differences disappeared post ASE training period. During recovery from incremental exercise, before ASE training, mean duration of all normal to normal RR intervals (RR values) were higher ($p<0.05$), and the ratio between low and high frequency components was lower ($p<0.05$) in the overweight group compared to those in the normal weight group. Higher mean RR values in the overweight group were maintained post ASE training period ($p<0.05$).

Conclusion: The present study suggested that in response to high-intensity exercise, parasympathetic nerve activity is predominant in young overweight adults. ASE training for 2 months improved cardiac autonomic activity in response to incremental exercise in overweight young adults.

Keywords: Heart rate variability, Body mass index, Effort

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Obesity and overweight prevalence have risen dramatically in recent decades. Meanwhile, it is known that obesity and being overweight are associated with the wide ranges of metabolic, autonomic, and cardiovascular diseases (CVD)[1], such as: heart failure, coronary artery disease (CAD), sudden cardiac death, and atrial fibrillation[2].

Spectral analysis of heart rate variability (HRV) has been widely applied as a non-invasive tool for evaluating sympathetic and parasympathetic nerve outflows to the heart[3]. HRV has been associated with the presence and prognosis of cardiac disorders, including heart failure, CAD, and fatal arrhythmia[3]. Data have suggested that the high frequency (HF) power of HRV reflecting cardiac parasympathetic function is reduced in obese adults relative to normal

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weight adults[4,5]. Low levels of parasympathetic function are powerful predictors of mortality caused by myocardial infarction (MI)[5].

It has been shown that exercise training has the ability to reverse autonomic dysfunction in patients with MI, CAD, or heart failure[3]. Although the exact mechanisms through which increased parasympathetic function contributes to cardiovascular health are unclear, it is likely that increased parasympathetic function antagonizes sympathetic effects at the ventricular level, concomitantly improving cardiac electrical stability and protecting against MI[5].

Arm swing exercise (ASE) has been extensively practiced in China and Thailand for over 50 years. This type of exercise is categorized as low-intensity exercise based on an approximately 23% level of maximal oxygen consumption (VO_2 max) and 45% maximal HR[6,7]. The authors' previous study reported significant increases in exercise capacity and peak VO_2 in overweight and normal weight subjects participating in ASE training[8]. These increases are associated with increased cardiac parasympathetic outflow and thus increased HRV[9,10]. Felber et al[11] reported percentage increase in HRV values in overweight subjects exercised regularly was lower than of normal weight subjects exercised at the same frequency. Nevertheless, those results were obtained from resting condition. Moreover, data concerning different responses in HRV values during exercise between overweight and normal weight persons are limited. Accordingly, the present study sought to evaluate cardiac autonomic function in response to exercise in overweight and normal weight young adults, and to test the hypothesis that ASE training would improve HRV in the young overweight adults. It was predicted that preliminary differences in HRV values between the overweight and normal weight young adults would diminish with ASE training.

Materials and Methods

The present study was quasi-experimental design (two-group pretest-posttest design). Healthy sedentary young adults dwelling in Mueang District, Chonburi Province, Thailand were announced and recruited. Forty participating subjects were divided into 2 groups in accordance with age and sex: 1) overweight [n = 20; 4 males and 16 females, aged 20±0.36 years, body mass index (BMI) 27.5±1.52 kg/m²]; and 2) normal weight (n = 20; 4 males and 16 females, aged 20±0.66 years, BMI 20.5±1.75 kg/m²). The overweight and normal weight groups were classified according to the World Health Organization BMI classification. Overweight is defined as BMI of 25.0 to 29.9 kg/m² and normal weight is defined as BMI of 18.5 to 24.9 kg/m²[12]. Prior to being enrolled, subjects were informed of their role in the study, both verbally and in written by a researcher. The consent form provided information regarding collection, use, and storage of subject data. The consent form and study protocols were in accordance with the ethical standards of the Human Research Ethics Committee (HREC) of Burapha University (approval no.40/2557), as well as with the 1964 Helsinki Declaration and its later amendments. The HREC were also informed of these subsequent study protocol alterations.

The WINPEPI program was employed to calculate the sample size for the present study. A previous study showed that low frequency (LF) power (nu) was higher in overweight subjects (68.18±11.16) compared to normal weight subjects (47.20±12.54)[13]. Sample size was calculated using a power of 80% with a significance level of 0.05. Accordingly, the proposed size of the present study was 18 subjects per group, totaling 40 subjects overall accounting for a 10% drop-out rate.

A preliminary screening was conducted with health questionnaires to collect medical history and medical examinations in order to obtain vital signs, thus ensuring that subjects were not smokers or drinkers and free from certain diseases, for instance cardiovascular, neuromuscular, orthopedic, liver, or renal diseases. Measurements of height and body mass (Tanita UM076, Japan) were taken, from which BMIs were determined. Body composition was measured in the standing position based on biceps, triceps, subscapular, and suprailiac skinfold thickness using a standard skinfold caliper (Beta Technology Incorporated Cambridge, Maryland, USA)[14]. Fat distribution was assessed by measuring waist and hip circumferences and their ratio using a standard measuring tape. Waist circumference was measured at the end of a normal expiration and at the mid-point between the bottom rib and the superior iliac spine. In addition, hip circumference was measured on a horizontal plane at the site of maximum extension of the buttocks[15].

Cardiac autonomic function was evaluated with HRV utilizing Polar RS800CX. This device has been validated for measuring heart rate (HR) and HRV[16]. The Polar system consists of a HR monitor with bundled software (Polar Pro Trainer 5) employed to obtain HRV values. Analysis of HRV in the time domain consisted of mean RR, the transverse and longitudinal diameters of the Poincaré plot (SD1 and

SD2), the root mean square differences of successive NN intervals (RMSSD), and the number of adjacent NN intervals differing by more than 50 millisecond (pNN50). Analysis in the frequency domain involved evaluating values of total power (TP 0.003 to 0.400 Hz), very low frequency (VLF 0.003 to 0.040 Hz), low frequency (LF 0.040 to 0.150 Hz), high frequency (HF 0.150 to 0.400 Hz), and the LF/HF ratio.

All subjects performed an incremental exercise test prior and subsequent to the exercise training program using an electromagnetic cycle ergometer (Rollfit 850, Taiwan). They started with a 5-minute warm-up at a workload of 0 watts with a cadence of 60 revolutions per minute (rpm). Workloads were increased by 20-30 watts every 3 minutes and subjects were required to maintain a 60 rpm cadence. The test was terminated when subjects attained maximum symptoms of dyspnea (Borg ratings of perceived dyspnea: RPD 9 to 10) or fatigue (Borg ratings of perceived exertion: RPE 18 to 20), when cadence could no longer be maintained at 60 rpm, or HR exceeded the generally accepted value of HR max (i.e., 220 – age)[17]. To determine cardiac autonomic function, a chest belt of Polar RS800CX which detected HR was attached around subjects' chests throughout experimentation. HR obtained throughout exercise and 5-minutes immediately after exercise (recovery) were applied to evaluate HRV.

During training, all subjects performed ASE for 30 minutes/session, three times weekly over two months. In the ASE starting position, subjects stood firmly on the ground at shoulder width apart. They were asked to keep their trunks straight with their arms hanging naturally. Then, both arms were swung forward at about 30° and backwards at about 60° slowly and continuously at a rate of roughly 42 times/minute[18]. During the training period, subjects were requested to carry on with their daily routine activities including physical activity and food consumption behaviors. They were also closely followed via telephone communication by a researcher with the goal of encouraging completion of the program. Subjects who could not consecutively perform the intervention, for example having a health problem or requesting to stop were asked to inform a researcher and then considered for exclusion from the study. If in the unlikely instance, subjects were injured as a result of participating in the intervention, he or she would be compensated for the treatment costs by the research team. Data obtained from any subject who had not properly completed the program would be collected but not included in the analysis.

Subjects' blood pressure (BP) was measured immediately after their incremental exercise test using a digital BP monitor (Microlife BP 3AQ1, Switzerland). Subjects were sat in the sitting position with their arm and back supported. The BP cuff was closely wrapped around each subject's arm. The lower edge of the cuff was placed roughly 1 inch above the bend of the elbow, BP was then measured. All measurements were performed at the same time of the day and under noise-free environmental conditions.

All subjects' information and data were confidentially collected and kept for 2 years post dissemination of research findings. After the 2 years, we will deliver a completely deidentified data set to an appropriate data archive for sharing purposes. Study subjects were informed of their summary results by a researcher accordingly. In addition, data were stored in a secured computer and rechecked prior to analysis.

SPSS statistics software (IBM Inc., Armonk, NY, USA) was used to analyze the data. All data were expressed as mean±SD. Repeated-measures ANOVA was applied to assess the differences within each group (pretest-posttest analysis) as well as between the overweight and normal weight groups. When a significant difference was seen, post hoc analysis using the Bonferroni adjustment was performed. Statistical significance was achieved at $p<0.05$.

Results

Physical characteristics of subjects

Body mass, BMI, waist and hip circumferences, waist to hip (W/H) ratio, body fat percentage, fat mass, and fat-free mass before training in the overweight group were significantly higher than in the normal weight group ($p<0.05$); these differences were maintained post ASE training period ($p<0.05$).

There was a significant decrease in W/H ratio in the normal weight group after the 2-month ASE training ($p<0.05$). In the overweight group, there were no significant changes in anthropometric variables post 2-month ASE training (Table 1).

Cardiac autonomic function during low-intensity exercise

Before training, mean HR in the overweight group was significantly higher than in the normal weight group ($p<0.05$). This difference was not observed after the ASE training period.

There were no significant changes in HRV variables after the 2-month ASE training in both the overweight and normal weight groups (Table 2).

Table 1. Physical characteristics of overweight and normal weight groups before and after the 2-month ASE training

	Normal weight group (n = 20), Mean±SD		Overweight group (n = 20), Mean±SD	
	Before	After	Before	After
Sex (male/female), n	4/16	4/16	4/16	4/16
Age (years)	20.11±0.7	20.28±0.7	20.06±2.4	20.23±2.4
Height (m)	1.61±0.1	1.61±0.1	1.67±0.1	1.67±0.1
Body mass (kg)	50.82±6.8	50.34±6.8	82.74±14.9#	74.61±7.7#
BMI (kg/m^2)	20.50±1.8	19.31±1.8	29.46±3.5#	28.01±2.0#
Waist circumference (cm)	67.79±5.9	66.72±5.7	92.61±13.2#	88.50±6.9#
Hip circumference (cm)	90.05±6.0	91.36±5.6	108.02±6.0#	107.99±6.4#
W/H ratio	0.75±0.1	0.73±0.0*	0.86±0.1#	0.83±0.1#
Body fat (%)	20.14±6.6	18.79±6.2	29.56±6.5#	30.66±7.8#
Fat mass (kg)	10.24±4.0	9.50±3.6	23.75±6.6#	22.73±5.9#
Fat-free mass (%)	79.91±6.6	81.23±6.2	70.42±6.5#	69.34±7.8#
Fat-free mass (kg)	40.58±6.7	40.84±6.4	56.86±12.2#	51.88±9.1#

ASE=arm swing exercise; SD=standard deviation; BMI=body mass index; W/H=waist to hip circumference

* Significantly different from before training ($p<0.05$), # significantly different from normal weight group at the same time period ($p<0.05$)

Table 2. Cardiac autonomic function during low-intensity exercise of overweight and normal weight groups before and after the 2-month ASE training

	Normal weight group (n = 20), Mean±SD		Overweight group (n = 20), Mean±SD	
	Before	After	Before	After
Mean RR (ms)	525.16±52.2	554.78±88.3	472.39±88.6	496.51±90.7
SD1 (ms)	20.14±10.5	22.31±15.9	18.28±12.14	19.32±11.4
SD2 (ms)	67.43±20.1	65.62±24.3	72.31±34.2	74.65±29.7
RMSSD (ms)	23.78±16.6	24.82±18.5	20.42±15.6	22.36±16.4
pNN50 (%)	5.26±7.2	5.71±8.7	4.58±6.0	4.75±7.6
TP (ms^2)	1,824.73±346.7	1,704.44±288.5	1,606.34±375.7	1,521.67±362.8
VLF (ms^2)	1,158.45±676.4	1,062.97±712.3	921.91±623.4	914.62±594.7
LF (ms^2)	463.21±265.5	448.72±278.6	513.26±255.6	531.52±282.4
HF (ms^2)	232.77±314.6	243.56±296.3	214.28±246.8	224.35±283.5
LF/HF ratio	2.16±2.24	2.07±2.07	2.42±2.03	2.25±2.17
Mean HR (/min)	95.00±18.6	93.85±19.7	114.98±16.6#	111.17±18.3

ASE=arm swing exercise; SD=standard deviation; Mean RR=mean duration of all normal to normal RR intervals; SD1=transverse diameters of the Poincaré plot; SD2=longitudinal diameters of the Poincaré plot; RMSSD=root mean square differences of successive NN intervals; pNN50=number of adjacent NN intervals which differ by more than 50 ms; TP=total power; VLF=very low frequency; LF=low frequency; HF=high frequency; Mean HR=mean heart rate

Significantly different from normal weight group ($p<0.05$)

Cardiac autonomic function during moderate-intensity exercise

There were no significant differences in HRV variables between the overweight and the normal weight groups both before and after the 2-month ASE training.

There were also no significant changes in HRV variables post 2-month ASE training in both the overweight and the normal weight groups (Table 3).

Cardiac autonomic function during high-intensity exercise

Prior to training, the SD2 value and mean HR in the overweight group were significantly lower than in the normal weight group ($p<0.05$). However, these differences disappeared subsequent to the ASE training period.

There were significant decreases in the SD2 value and mean HR in the normal weight group after the

Table 3. Cardiac autonomic function during moderate-intensity exercise of overweight and normal weight groups before and after the 2-month ASE training

	Normal weight group (n = 20), Mean±SD		Overweight group (n = 20), Mean±SD	
	Before	After	Before	After
Mean RR (ms)	502.44±63.5	516.23±70.1	493.45±68.2	527.20±95.8
SD1 (ms)	15.18±8.2	16.89±7.6	11.32±5.6	13.13±6.8
SD2 (ms)	64.28±10.9	62.34±12.3	65.23±11.5	59.32±12.4
RMSSD (ms)	16.67±7.2	18.41±7.6	15.34±6.8	17.11±8.3
pNN50 (%)	3.14±1.5	3.26±1.1	2.62±1.2	3.04±1.4
TP (ms^2)	1,201.36±650.4	1,174.78±628.1	972.47±583.3	956.28±671.6
VLF (ms^2)	692.31±432.6	612.45±459.2	593.68±418.2	526.75±422.4
LF (ms^2)	337.16±181.6	314.87±159.3	317.23±166.7	340.55±185.6
HF (ms^2)	120.65±138.5	125.62±114.3	112.56±110.2	118.32±98.5
LF/HF ratio	3.76±2.2	3.65±2.8	3.72±2.9	3.56±3.2
Mean HR (/min)	145.44±17.2	142.27±18.5	138.19±18.1	130.28±17.7

ASE=arm swing exercise; SD=standard deviation; Mean RR=mean duration of all normal to normal RR intervals; SD1=transverse diameters of the Poincaré plot; SD2=longitudinal diameters of the Poincaré plot; RMSSD=root mean square differences of successive NN intervals; pNN50=number of adjacent NN intervals which differ by more than 50 ms; TP=total power; VLF=very low frequency; LF=low frequency; HF=high frequency; Mean HR=mean heart rate

Table 4. Cardiac autonomic function during high-intensity exercise of overweight and normal weight groups before and after the 2-month ASE training

	Normal weight group (n = 20), Mean±SD		Overweight group (n = 20), Mean±SD	
	Before	After	Before	After
Mean RR (ms)	475.37±72.0	491.73±68.5	526.68±76.9	548.22±85.2
SD1 (ms)	8.16±5.6	8.21±5.2	6.72±5.0	7.11±5.8
SD2 (ms)	61.25±11.8	58.27±10.2*	52.13±12.1#	48.14±11.7
RMSSD (ms)	9.99±8.4	12.46±6.7	8.11±6.6	10.77±7.2
pNN50 (%)	1.41±1.9	1.66±1.5	0.84±0.9	1.25±1.2
TP (ms^2)	482.66±351.3	437.95±238.6	432.52±248.9	405.81±271.4
VLF (ms^2)	289.10±293.9	257.61±149.4	278.35±168.3	258.25±227.5
LF (ms^2)	150.65±211.9	124.58±105.0	127.05±150.8	138.89±199.7
HF (ms^2)	40.89±68.8	45.76±24.4	36.11±40.7	38.04±65.7
LF/HF ratio	5.43±3.4	5.32±3.3	5.66±3.2	5.43±3.1
Mean HR (/min)	167.10±22.2	163.12±21.8*	146.76±21.2#	144.28±23.6

ASE=arm swing exercise; SD=standard deviation; Mean RR=mean duration of all normal to normal RR intervals; SD1=transverse diameters of the Poincaré plot; SD2=longitudinal diameters of the Poincaré plot; RMSSD=root mean square differences of successive NN intervals; pNN50=number of adjacent NN intervals which differ by more than 50 ms; TP=total power; VLF=very low frequency; LF=low frequency; HF=high frequency; Mean HR=mean heart rate

* Significantly different from before training (p<0.05), # significantly different from normal weight group (p<0.05)

2-month ASE training ($p<0.05$). In the overweight group, there were no significant changes in HRV variables post 2-month ASE training (Table 4).

Cardiac autonomic function 5-min after incremental exercise

Before training, mean RR value was significantly higher and LF/HF ratio was significantly lower in the overweight group than in the normal weight group ($p<0.05$). The results note that a higher mean RR value in the overweight group was maintained after the ASE training period ($p<0.05$).

There were no significant changes in HRV variables in both the overweight and normal weight groups after the 2-month ASE training (Table 5).

HR and BP immediately after incremental exercise

Before training, HR was significantly lower

Table 5. Cardiac autonomic function 5-minute after incremental exercise of overweight and normal weight groups before and after the 2-month ASE training

	Normal weight group (n = 20), Mean±SD		Overweight group (n = 20), Mean±SD	
	Before	After	Before	After
Mean RR (ms)	533.42±81.5	572.84±89.0	630.73±108.6#	651.30±122.5#
SD1 (ms)	14.84±23.5	12.45±8.2	21.88±29.8	18.04±11.4
SD2 (ms)	85.73±52.5	89.70±25.9	108.21±32.8	111.82±41.7
RMSSD (ms)	21.03±33.3	17.63±11.6	31.01±42.2	25.55±16.1
pNN50 (%)	1.25±3.7	1.68±2.9	3.06±5.6	3.73±5.5
TP (ms^2)	1,156.95±1,550.5	1,542.98±1,128.4	1,825.36±1,272.4	1,649.42±1,781.1
VLF (ms^2)	1,998.42±5,634.7	1,094.30±742.6	2,088.41±2,399.1	1,585.15±2,496.3
LF (ms^2)	722.61±1,912.8	439.65±416.8	699.00±1,005.6	529.64±397.4
HF (ms^2)	1,035.85±1,900.3	132.22±145.1	511.62±1,436.6	224.50±195.9
LF/HF ratio	4.38±2.3	5.00±3.4	3.19±1.7#	4.21±3.6
HR recovery (/min)	44.3±18.4	52.0±15.7	33.4±13.0	34.0±19.3
HR reserve (/min)	25.5±13.3	29.8±12.6	19.6±10.3	23.3±18.5

ASE=arm swing exercise; SD=standard deviation; Mean RR=mean duration of all normal to normal RR intervals; SD1=transverse diameters of the Poincaré plot; SD2=longitudinal diameters of the Poincaré plot; RMSSD=root mean square differences of successive NN intervals; pNN50=number of adjacent NN intervals which differ by more than 50 ms; TP=total power; VLF=very low frequency; LF=low frequency; HF=high frequency; HR=heart rate

Significantly different from normal weight group ($p<0.05$)

Table 6. Heart rate and blood pressure immediately after incremental exercise of overweight and normal weight groups before and after the 2-month ASE training

	Normal weight group (n = 20), Mean±SD		Overweight group (n = 20), Mean±SD	
	Before	After	Before	After
HR (/min)	119.63±25.8	115.00±18.1	108.13±24.4#	112.61±15.4
SBP (mmHg)	126.93±19.4	121.10±12.0	128.68±13.1	126.58±12.7
DBP (mmHg)	75.40±12.0	71.10±15.7	77.32±10.2	75.84±11.2
PP (mmHg)	51.53±20.2	50.00±18.8	54.37±15.3	51.74±10.7
MAP (mmHg)	91.58±11.4	88.10±7.3	93.77±10.1	90.42±10.5
RPP (mmHg/min)	13,921.21±3,283.3	10,854.42±2,243.8	14,162.73±5,148.6	11,016.80±1,748.0

ASE=arm swing exercise; SD=standard deviation; HR=heart rate; SBP=systolic blood pressure; DBP=diastolic blood pressure; PP=pulse pressure; MAP=mean arterial pressure; RPP=rate-pressure product

Significantly different from normal weight group ($p<0.05$)

in the overweight group than in the normal weight group ($p<0.05$). This difference was not witnessed subsequent to the ASE training period.

There were no significant changes in BP variables in both the overweight and normal weight groups after the 2-month ASE training (Table 6).

Discussion

The present study aimed to evaluate cardiac autonomic function in response to incremental exercise in overweight sedentary young adults, and to evaluate the effects of ASE training on cardiac autonomic function in response to exercise. To our knowledge, comparative evaluations of cardiac autonomic function in response to incremental exercise in overweight and normal weight young adults have not previously been described. The principal results obtained in the present study showed that in response to high-intensity exercise, the overweight young adults exhibited higher parasympathetic function than the normal weight young adults.

It has been shown that excess weight is associated with a range of health risks in young people and adults[4]. Previous reports have demonstrated autonomic dysfunction in overweight subjects[13,19,20]. In these circumstances, parasympathetic function is reduced and sympathetic function predominates in overweight subjects[21]. HRV results from the interplay between the various physiological mechanisms regulate HR. Moreover, HR regulation is predominantly governed by sympathetic and parasympathetic neural function[13].

Visceral fat accumulation has been reported to be associated with HRV[22]. Chronic low-grade inflammation, insulin resistance, and autonomic dysfunction are present at an early age in obese youths[23]. Findings by Adam et al[19] support that a reduced HRV in overweight subjects results from inflammatory processes. It is also claimed that a reduced glucose threshold and hyperinsulinemia are the primary pathologies disturbing sympathovagal balance[13,20]. Other potential mechanisms include hyperleptinemia, activation of the renin-angiotensin-aldosterone system, and mitochondrial dysfunction. Altered neurohumoral signals arising from the hypothalamic-pituitary-adrenal axis, increased adipokines, and dyslipidemia can also be contributing factors to a reduced HRV[24].

During low-intensity exercise, overweight subjects presented higher mean HR than normal weight subjects. On the contrary, during high-intensity exercise, they displayed significantly lower mean HR and SD2 values than the normal weight subjects, thus indicating lower sympathetic activity. In obese individuals, sympathetic nerve hyperactivity is marked at rest; nonetheless, during physiological stimuli, a reduced sympathetic nervous responsiveness has been observed[24]. For example, during 30% of maximum voluntary contraction, muscle sympathetic nerve activity was blunted in obese subjects[25]. What's more, during post-handgrip circulatory arrest, muscle sympathetic nerve activity responses were blunted in obese subjects relative to lean subjects[25]. The authors suggest that metaboreceptors were impaired in the obese subjects during exercise. Dipla et al[24]. reported an attenuated increase in exercise HR associated with a lower vagal withdrawal in obese subjects compared with normal weight subjects. These mechanisms could partly explain our results where the SD2 component of HRV and mean HR during high-intensity exercise were significantly lower in the overweight subjects.

During recovery from the incremental exercise, overweight subjects had a significantly higher mean RR value and lower LF/HF ratio than the normal weight subjects. These results reflect that high parasympathetic activity remained in overweight subjects after the exercise session. Dipla et al[24]. also reported lower vagal withdrawal during recovery in obese subjects compared with normal weight subjects. The present results also showed a lower HR was observed in overweight subjects, although a difference in BP variables was not observed. The autonomic responses to exercise are orchestrated by the interactions of several mechanisms[26]. Excess body fat in obese and overweight individuals can affect the catecholamine response to various stimuli. Several studies have reported lower plasma catecholamine concentrations in obese subjects compared with non-obese subjects in response to submaximal or maximal exercise. This low catecholamine response reflects decreased sympathetic activity. Although the relationship between sympathetic activity and obesity is not well established, some authors have suggested that low sympathetic activity may lead to the development of obesity. Furthermore, a decreased catecholamine response could affect α- and β-adrenoceptor sensitivity in adipose tissue, decreasing lipolysis and increasing fat storage[27]. In obese animals, a decreased level of sympathetic nervous system activity may lead to decreased lipolysis and increased lipogenesis[28]. These effects may be the contributing factors causing overweight and obese individuals to have more difficulty in losing weight during exercise periods.

The authors also hypothesized that a preliminary difference in HRV values in response to incremental exercise between overweight and normal weight subjects would diminish after the ASE training. The results showed that a difference in mean HR during low-intensity exercise, the differences in SD2 value, mean HR during the high-intensity exercise, and a difference in LF/HF ratio during recovery from the exercise had vanished post ASE training period. These results suggest that ASE training can contribute to normalization of existing alterations in autonomic nerve activity in the overweight subjects as well as serving as a preventative factor in the normal weight subjects; hence, enabling healthy development of autonomic nerve activity.

The present study has some limitations. A limited intervention period (2 months) might be insufficient to disclose additional changes in cardiac autonomic function variables. A longer training period (i.e., 3 months or more) may result in such physiological changes.

Conclusion

The present study suggested that in response to high-intensity exercise, parasympathetic nerve activity is predominant in overweight young adults.

ASE training for 2 months, 30 minutes/day, 3 days/week improved cardiac autonomic activity in response to incremental exercise as well as during recovery in young overweight adults.

What is already known on this topic?

Reduced HRV is associated with the presence and prognosis of cardiovascular diseases. Data have suggested that HRV is reduced in overweight individuals relative to normal weight individuals. However, the previous results are attained from resting condition. Moreover, exercise training has been shown to improve cardiac autonomic function in the overweight individuals. Notwithstanding, data concerning the effects of ASE training on HRV responses to incremental exercise are limited.

What this study adds?

Overweight young adults presented higher parasympathetic activity in response to high-intensity exercise indicated by lower SD2 and mean HR in comparison to young normal weight adults. During recovery, they also exhibited higher parasympathetic activity indicated by lower LF/HF ratio and higher mean RR. ASE training for 2 months at a frequency of 30 minutes/day, 3 days/week improved cardiac autonomic activity among the young overweight adults in response to incremental exercise and during recovery. Initial differences in HRV values between the overweight and the normal weight young adults were reduced with ASE training.

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Authors' contributions

Prasertsri P designed this experiment, collected, and analyzed data and wrote this manuscript. Leelayuwat N wrote and proofed the manuscript.

Potential conflicts of interest

The authors declare no conflict of interest.

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