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Effects of Autogenic Training on Heart Rate Variability and Heart Rate Recovery in Japanese Obese/Overweight Male Workers

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Abstract

Objective: Obesity-induced autonomic nervous system (ANS) dysfunction is related to cardiac disease. The purpose of this study is to examine the effect of autogenic training (AT), a therapeutic relaxation technique, on cardiac ANS functions as evaluated by heart rate variability (HRV) and heart rate recovery (HRR) in Japanese obese/overweight subjects.

Methods: Subjects were 40 obese/overweight male workers (42.7 ± 8.8 years old, BMI 28.8 ± 3.3 kg/m^2). The subjects were randomly assigned to an AT intervention group and a control group. Subjects of the intervention group were required to perform the AT training procedures (first-third steps) for three months, while the control group participants were waiting. Before and after intervention, HRV was calculated using a 24 hr Holter ECG, and HRR was assessed by a treadmill test. In addition, Profile of Mood States (POMS), job stress and sleep conditions were assessed. Effects of AT intervention were statistically examined using analysis of covariance (ANCOVA).

Results: For the HRV, the ratio of the Low Frequency to the High Frequency (LF/HF) during sleep was significantly reduced in the AT group (-39.2% and -0.6%, respectively, p=0.009). HRR was lengthened in the AT group (5.2% and 0.6%, respectively, p=0.042). In addition, the Confusion-Bewilderment score in POMS was improved in the AT group. However, mediation analysis indicated that the Confusion-Bewilderment score was not considered as a mediator between AT and ANS.

Conclusions: A three month AT intervention improved cardiac ANS activities in Japanese obese/overweight men. These results suggest the beneficial effects of AT on obesity-related cardiovascular conditions.

Keywords: Randomized control trial; Relaxation; Autonomic nervous system; Obesity; Sympathetic/parasympathetic

Introduction

Obesity induces autonomic nervous system (ANS) dysfunction, which is related to an increased risk of hypertension, diabetes mellitus, atrial fibrillation, cardiovascular disease, congestive heart failure, sudden death, and all causes of mortality [1-4].

Heart rate variability (HRV) in the ambulatory condition and heart rate recovery (HRR) after exercise are widely used as standard tools for assessing the ANS activities. Low HRV and short HRR are generally considered as unfavorable ANS function [5,6]. Previous studies indicated a close association of obesity with reduced HRV and HRR [7-9], and that a weight loss in obesity increased HRV and prolonged HRR [10-12].

Autogenic training (AT) is a self-administered relaxation technique developed by Shultz et al. [13] and widely used for the improvement of various psychological stress-related conditions such as anxiety, headache, irritable bowel syndrome, and other psychosomatic diseases [14-16]. From the practical point of view, comparing with other relaxation techniques, AT technique is easier for the subjects to master and execute by themselves in daily life because its procedure is simple and well structured. Although the exact mechanisms of the AT on these conditions are still unclear, some studies demonstrate that AT improved HRV in subjects with some sort of mental distress such as fire service workers or patients with anxiety disorders [17,18]. These results suggested that AT might modify ANS function in a similar fashion to other relaxation techniques or biofeedback procedures [19,20]. However, very few studies have assessed the relationship of AT with ANS in healthy subjects without psychosomatic disorders. In this randomized clinical study, we examined the effect of AT on ANS functions in healthy overweight/obesity men.

Methods

Subjects

Fifty-five overweight/obese (BMI ≥ 25 kg/m^2) working-age men who participated in a weight reduction program conducted by Aichi Medical University Institute of Physical Fitness, Sports Medicine and Rehabilitation, were enrolled [21]. All the participants were naive to AT. The protocol of the study, which was approved by the Ethical Committee at Aichi Medical University, was explained in detail and a

written informed consent was obtained from each subject. One subject who was under 20 years old and one subject who refused to undergo a Holter ECG was excluded from this study. A total of 53 participants were randomly assigned either to the AT intervention (n=25) or control (n=28) group (Figure 1).

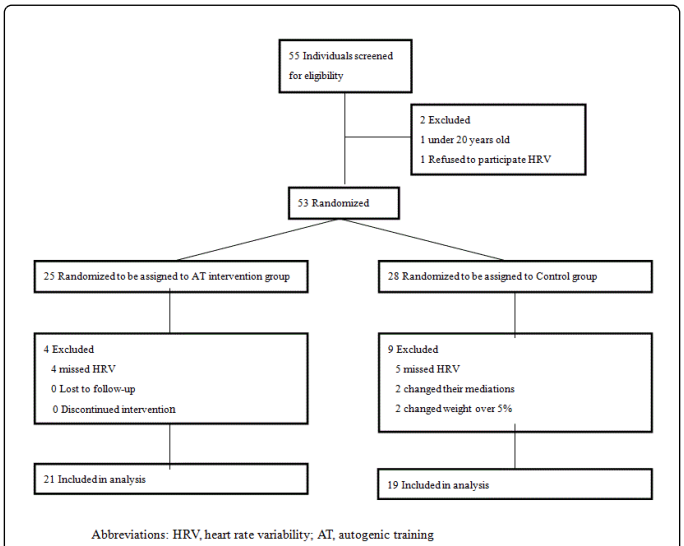

Figure 1: Flow of participants through the study phases.

Two subjects were excluded because they started their medical treatment during the three-month intervention. Two subjects were also excluded because their body weight changed over 5% from baseline during the three months [10-12]. Nine subjects were excluded because of technical error in collecting the Holter ECG data and/or Exercise test. In total, the data of 40 subjects (AT intervention group: n=21, Control group: n=19, Figure 1) was analyzed in the study. All of them were regular [5,22] employees working at several small and medium-sized enterprises in Japan. No subject was taking β-blockers, any cardiac medication that could affect their HR, any diabetic medication including insulin, or treatment of sleep apnea syndrome (SAS) [3,23,24]. No subject had any history of cardiovascular diseases, sleep disorders, and other psychosomatic or mental illness [5,25]. No subject changed their smoking habits during the study [5,26].

Study design

Participants were randomly assigned to the AT intervention or control group. Participants of the AT intervention group were required to carry out AT twice every day for three months, while those of the control group were waiting without any instructions (Figure 1). All participants were asked to maintain their habits of smoking, alcohol consumption, physical activity, and food intake during the intervention period [5,26,27]. At the start and end of the intervention period, physical examination was conducted. Blood sampling was conducted in the morning after an overnight fast. Plasma glucose was analyzed in duplicate using the hexokinase method, serum insulin was measured using the chemiluminescence enzyme immunoassay method, and the Homeostasis Model Assessment score of insulin resistance (HOMA-R) was calculated with the following formula: fasting insulin (mU ml^{-1}) × fasting glucose (mmol l^{-1})/405. Hemoglobin A1c (HbA1c) was measured by the latex agglutination method. All blood sample analyses were performed in the same laboratory (SRL, Nagoya, Japan). Blood pressure was measured three times with a fully automated sphygmomanometer (TM-2655; A&D, Tokyo, Japan) after sitting quietly for five minutes. The average of the three BP measurements was calculated as Rest BP. BMI was calculated as weight (kg)/height $(m)^2$.

Daily physical activity was measured using a triaxial accelerometer (Carpod, Medi Link, Toyota, Japan). On regular working days before and after intervention, the subjects wore the accelerometer for 24 hr. At the same time, HRV and HRR data were collected.

Medical history, current therapeutic regime, smoking habit, and alcohol consumption were recorded by using a self-report questionnaire. Psychological conditions were assessed by the Profile of Mood States (POMS) brief form Japanese version [28]. Job strain, as defined by the job demands/control model [29], was measured by the Japanese short version of the Job Content Questionnaire (JCQ) at each examination. Sleep condition was assessed by using the Japanese version of the Pittsburgh Sleep Quality Index (PSQI) [30,31].

Autogenic training

Before the AT intervention, the subjects of AT group were instructed in the tranquility (calmness of feeling), first (heaviness exercise) and second (warmth exercise) standard AT exercise by a trained therapist. The AT procedure was instructed by the same therapist (T.H.). The training was conducted during a 60 min group (2-4 participants) session. They were requested to perform the AT exercises twice (after awaking and before sleeping) a day, and to record a log of the times of their AT exercise for three months.

Heart rate variability

Before and after intervention, 2-channel 24 hr ambulatory ECG was conducted. The HRV was analyzed on a Holter analysis system (ML analyzer; Medi Link, Toyota, Japan). The digitized R-R intervals were recorded and stored, and the power spectral densities were computed using the maximum entropy method (MEM) from the 24 hr and nocturnal data [31]. The power spectral densities were analyzed in three areas of concentration of spectral power by means of MEM. In these two areas, low-frequency power (LF: 0.04-0.15 Hz) was analyzed as an index of the balance of sympathetic and parasympathetic nervous activity, and high-frequency power (HF: 0.15-0.4 Hz) was analyzed as an index of parasympathetic nervous activity. The ratio of LF to HF (LF/HF), an indirect index of sympathetic nervous system activity [5,32], was calculated for each data set.

Heart rate recovery

The subjects performed a reach symptom-limited maximal treadmill test (STRESS TEST SYSTEM ML-6500: Fukuda Denshi, Tokyo, Japan) using a Bruce protocol [33] at the checkups before and after intervention. Medications were not changed or stopped before testing. The subjects wore a mask to estimate their ventilation by collecting real time VO_2 and VCO_2 (OXYCON-PRO: Fukuda Denshi, Tokyo, Japan). Peak exercise, the criteria for exercise cassation, was defined as symptom-limited or achievement of the point when VCO_2 surpassed VO_2, whereby the respiratory exchange ratio (RER value) was greater than 1.04. Every one minute during and after exercise, and at peak exercise, heart rate (measured by ECG in 12 derivations) and blood pressure (measured by arm-cuff sphygnomanometry) were collected. HRR was defined as the HR difference between at the peak and one minute after the peak [34].

Sample size

We designed the study to have 80% power to detect a 1.0 difference between the groups in the decreased range of LF/HF, according to previous studies to examine the effects of AT on HRV [17,35]. Alpha was set at 0.05. With this assumption, the sample size in this study was estimated as 21.

Statistical analysis

Data are expressed as mean ± SD. After examining the normality of distribution of all numerical variables using Shapiro–Wilk test, between-group differences at baseline were assessed using by the unpaired t test (normally distributed variables) or Mann-Whitney's U test (non-normally distributed variables). Chi-square test was used to examine the difference in categorical variables.

At the baseline, two variables, Job-control score of JCQ and Vigor-Activity score of POMS, were skewed among two groups. Thus, Spearman's correlation coefficients were calculated to examine the association of HRV index and HRR with age [5], Job-control and Vigor-Activity.

To examine the significance of the effects of AT intervention, one-factor analysis of covariance (ANCOVA) with the three-month value as a dependent variable and with the use of a baseline value as covariate was used. Spectral measures (LF and HF) were log transformed (ln) prior to this analysis.

To assess whether the improvement in psychological or sleeping condition accounted for the improvement in ANS, mediation analysis [36,37] were performed. According to this analysis, when (1) there is a significant relationship between AT and ANS, (2) there is a significant relationship between AT and a variable, and (3) the variable is a significant predictor of ANS in an equation including both the variable and the AT, this variable is considered as a mediator.

Statistical significance was defined as $p<0.05$. SPSS 21.0 for Windows (SPSS Tokyo, Japan) was used for the statistical analysis.

Results

Baseline characteristics of variables

The baseline characteristics are presented in Table 1. There was no significant difference between the groups except for the Job-control score of JCQ and the Vigor-Activity score of POMS. Age was significantly correlated with nocturnal HF (r=-0.365, p=0.021) and HRR (r=-0.503, p=0.001). Job control score was significantly correlated with nocturnal LF (r=-0.382, p=0.015). There were no significant associations of Vigor-Activity score with HRV and HRR.

Variables	Autogenic training (n=21)	Control (n=19)	*p*
Age (years)	43.3 ± 9.8	42.0 ± 7.7	N.S
BMI (kg m^{-2})	29.0 ± 3.4	28.6 ± 3.2	N.S
Waist circumference (cm)	96.9 ± 8.5	95.1 ± 7.4	N.S
Rest SBP (mmHg)	135.4 ± 13.3	128.4 ± 14.5	N.S
Rest DBP (mmHg)	84.9 ± 11.0	80.9 ± 9.4	N.S
Rest HR (bpm)	72.3 ± 10.8	70.8 ± 6.2	N.S
Glucose (mg dl^{-1})	100.2 ± 8.6	98.3 ± 8.6	N.S
Insulin (μU ml^{-1})	10.5 ± 5.1	10.7 ± 5.5	N.S
HOMA-R	2.6 ± 1.3	2.6 ± 1.5	N.S
HbA1c (%)	5.1 ± 0.4	5.2 ± 0.3	N.S
Current smoker, n (%)	5 (23.8)	6 (31.6)	N.S
Alcohol drinker, n (%)	3 (14.3)	3 (15.8)	N.S
Excise (Mets)	2.02 ± 0.85	2.39 ± 1.28	N.S
Anti-hypertensive drug use, n (%)	2 (10.5)	4 (19.0)	N.S
Anti-diabetic drug use, n (%)	0 (0)	0 (0)	N.S
Anti-hyperlipidemic drug use, n (%)	0 (0)	1 (5.3)	N.S
Stress and sleep condition score			
Job demand score	8.8 ± 2.4	8.7 ± 2.0	N.S
Job control score	8.3 ± 2.0	9.8 ± 1.8	0.017
Anger-Hostility score	4.6 ± 3.5	3.8 ± 3.2	N.S

Confusion-Bewilderment score	4.3 ± 2.0	4.3 ± 1.6	N.S
Depression-Dejection score	3.2 ± 2.9	2.1 ± 2.4	N.S
Fatigue-Inertia score	5.3 ± 3.8	5.5 ± 3.6	N.S
Tension-Anxiety score	5.2 ± 3.2	5.3 ± 4.6	N.S
Vigor-Activity score	6.5 ± 3.2	9.0 ± 4.2	0.04
PSQI score	5.1 ± 2.6	4.1 ± 2.6	N.S
Holter ECG			
24 hr average HR (bpm)	76.5 ± 9.6	81.1 ± 6.2	N.S
24 hr of LF	698.3 ± 567.3	503.7 ± 213.8	N.S
Log 24 hr of LF	6.30 ± 0.70	6.13 ± 0.42	N.S
24 hr of HF	540.5 ± 1155.4	156.7 ± 116.8	N.S
Log 24 hr of HF	5.35 ± 1.20	4.90 ± 0.52	N.S
24 hr of LF/HF	3.13 ± 1.41	3.88 ± 2.44	N.S
Nocturnal average HR (bpm)	65.3 ± 10.1	66.5 ± 6.6	N.S
Nocturnal value of LF	890.8 ± 688.0	575.5 ± 549.7	N.S
Log nocturnal value of LF	6.52 ± 0.75	6.13 ± 0.60	N.S
Nocturnal value of HF	827.8 ± 1353.7	389.1 ± 501.1	N.S
Log nocturnal value of HF	5.95 ± 1.10	5.58 ± 0.79	N.S
Nocturnal value of LF/HF	2.31 ± 1.88	2.10 ± 1.85	N.S
Exercise test			
VO_2 max (ml/min/kg)	29.6 ± 5.5	29.2 ± 4.5	N.S
HR at excise start (bpm)	77.4 ± 9.2	75.5 ± 8.2	N.S
HR at peak exercise (bpm)	150.4 ± 19.4	147.0 ± 13.6	N.S
HRR (sec)	19.3 ± 8.5	20.3 ± 5.8	N.S

BMI: Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HR: Heart Rate; HOMA-R: The Homeostasis Model Assessment of Insulin Resistance; HbA1c: Hemoglobin A1c; PSQI: The Pittsburgh Sleep Quality Index; LF: Low Frequency Power; HF: High Frequency Power; LF/HF: Ratio of Low to High Frequency Power; VO_2max: Volume per Time Oxygen Maximum; HRR: Heart Rate Recovery

Table 1: Characteristics of autogenic training (AT) group and control group at the baseline of the study.

Daily life activity, BMI, waist circumference and insulin sensitivity

Daily life activity, BMI, waist circumference and insulin sensitivity did not change during the intervention period (Table 2a).

Variables	AT intervention group (N=21)		Control group (N=19)		*p*1
	Baseline	3 months	Baseline	3 months	
SBP (mmHg)	135.4 ± 13.3	132.0 ± 14.3	128.4 ± 14.5	123.6 ± 17.8	N.S
DBP (mmHg)	84.9 ± 11.0	81.5 ± 9.9	80.9 ± 9.4	78.5 ± 14.8	N.S
HR (bpm)	72.3 ± 10.8	73.7 ± 12.5	70.8 ± 6.2	70.2 ± 7.4	N.S

Glucose (mg dl^{-1})	100.2 ± 8.6	98.8 ± 6.3	98.3 ± 8.6	98.2 ± 9.1	N.S
Insulin (μU ml^{-1})	10.5 ± 5.1	9.6 ± 4.4	10.7 ± 5.5	9.3 ± 5.0	N.S
HOMA-R	2.6 ± 1.3	2.4 ± 1.1	2.6 ± 1.5	2.3 ± 1.3	N.S
HbA1c (%)	5.1 ± 0.4	5.1 ± 0.4	5.2 ± 0.3	5.2 ± 0.2	N.S
Excise (Mets)	2.02 ± 0.85	2.09 ± 0.84	2.39 ± 1.28	2.24 ± 1.30	N.S
SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HR: Heart Rate; HOMA-R: The Homeostasis Model Assessment of Insulin Resistance; HbA1c: Hemoglobin A1c; 1: One Factor Analysis of Covariance (ANCOVA) with the baseline value as covariate.					

Table 2a: Physiological, biochemical and psychological variables at baseline and after autogenic training (AT) intervention or control for three months.

Effect of AT intervention on physiological, biochemical and psychological variables

Table 2 shows the physiological, biochemical and psychological variables before and after the three-month intervention. The AT intervention had no effect on almost all of these variables except for the Confusion-Bewilderment score of POMS. Confusion-Bewilderment score was significantly improved in the AT group compared to the control group (-16.3% and 16.3%, respectively; p=0.023, Table 2b).

Variables	**AT intervention group (N=21)**		**Control group (N=19)**		*p*1
	Baseline	**3 months**	**Baseline**	**3 months**	
Job demand score	8.8 ± 2.4	9.4 ± 2.2	8.7 ± 2.0	8.4 ± 2.3	N.S
Job control score	8.3 ± 2.0	9.0 ± 2.6	9.8 ± 1.8	9.8 ± 1.8	N.S
Anger-Hostility score	4.6 ± 3.5	4.2 ± 2.3	3.8 ± 3.2	4.0 ± 2.9	N.S
Confusion-Bewilderment score	4.3 ± 2.0	3.6 ± 1.7	4.3 ± 1.6	5.0 ± 2.3	0.023
Depression-Dejection score	3.2 ± 2.9	3.1 ± 3.0	2.1 ± 2.4	1.9 ± 1.8	N.S
Fatigue-Inertia score	5.3 ± 3.8	6.3 ± 3.8	5.5 ± 3.6	6.1 ± 4.1	N.S
Tension-Anxiety score	5.2 ± 3.2	5.1 ± 2.5	5.3 ± 4.6	4.7 ± 3.3	N.S
Vigor-Activity score	6.5 ± 3.2	6.8 ± 4.0	9.0 ± 4.2	9.8 ± 3.5	N.S
PSQI score	5.1 ± 2.6	5.4 ± 2.2	4.1 ± 2.6	4.2 ± 2.0	N.S
PSQI: The Pittsburgh Sleep Quality Index; 1: One factor analysis of covariance (ANCOVA) with the baseline value as covariate					

Table 2b: Physiological, biochemical and psychological variables at baseline and after autogenic training (AT) intervention or control for three months.

Effect of AT intervention on HRV

HRV index before and after intervention is shown in Table 3a. Nocturnal LF/HF was significantly lower in the AT group than in the control group (-39.2% and -0.6%, respectively; p=0.009). This significant effect of AT did not change even after adjusting for age (p=0.011). Other HRV indices were not affected by the intervention (Table 3a). There were no correlations between the change of nocturnal LF/HF and that of the PSQI score in both AT and control groups (r=0.153, p=0.507).

Variables	**AT intervention group (N=21)**		**Control group (N=19)**		**p1**
	Baseline	**3 months**	**Baseline**	**3 months**	
24 hr average heart rate (bpm)	76.5 ± 9.6	75.1 ± 9.8	81.1 ± 6.2	77.9 ± 6.2	N.S
Log 24 hr of LF	6.30 ± 0.70	6.31 ± 0.76	6.13 ± 0.42	6.17 ± 0.49	N.S
Log 24 hr of HF	5.35 ± 1.20	5.32 ± 0.97	4.90 ± 0.52	4.99 ± 0.79	N.S

24 hr of LF/HF	3.13 ± 1.41	3.07 ± 1.45	3.88 ± 2.44	3.78 ± 2.46	N.S
Nocturnal average heart rate (bpm)	65.3 ± 10.1	63.9 ± 9.6	66.5 ± 6.6	63.6 ± 6.2	N.S
Log nocturnal value of LF	6.52 ± 0.75	6.30 ± 0.90	6.13 ± 0.60	6.23 ± 0.62	N.S
Log nocturnal value of HF	5.95 ± 1.10	6.01 ± 1.10	5.58 ± 0.79	5.71 ± 1.00	N.S
Nocturnal value of LF/HF	2.31 ± 1.88	1.40 ± 0.44	2.10 ± 1.85	2.08 ± 1.65	0.009
HR: heart rate; LF: Low Frequency power; HF: High Frequency power; LF/HF: Ratio of Low to High Frequency power; 1: One factor analysis of covariance (ANCOVA) with the baseline value as covariate					

Table 3a: Holter ECG index including heart rate variability (HRV) at baseline and after autogenic training (AT) intervention or control for three months.

Effect of AT intervention on HRR

Table 3b shows the results of the exercise test before and after intervention. The intervention had no effects on VO_2 max and peak HR. A significant difference was observed in the HRR between the two groups (5.2% and 0.6%, respectively; p=0.042). After adjusting for age, this significant difference did not change (p=0.047).

Variables	AT intervention group (N=21)		Control group (N=19)		p1
	Baseline	3 months	Baseline	3 months	
VO_2 max	29.6 ± 5.5	27.3 ± 4.2	29.2 ± 4.5	29.6 ± 3.6	N.S
Heart rate at excise start (bpm)	77.4 ± 9.2	79.2 ± 14.3	75.5 ± 8.2	75.7 ± 8.4	N.S
Heart rate at peak exercise (bpm)	150.4 ± 19.4	139.3 ± 15.2	147.0 ± 13.6	144.7 ± 15.5	N.S
Heart rate recovery	19.3 ± 8.5	23.5 ± 11.1	20.3 ± 5.8	21.3 ± 5.7	0.042
VO_2 max: Volume per Time Oxygen Maximum; HR: Heart Rate; HRR: Heart Rate Recovery; 1: One factor analysis of covariance (ANCOVA) with the baseline value as covariate					

Table 3b: Exercise test index including heart rate recovery (HRR) at baseline and after autogenic training (AT) intervention or control for three months.

Mediation analysis

We conducted a mediation analysis [36,37] to clarify mediating roles of the psychological state (POMS) or sleep condition (PSQI) in linking between AT and ANS (nocturnal LF/HF and HRR). While the score of Confusion-Bewilderment of POMS significantly increased in the AT group, regression analysis did not reveal any significant relationship between the score and nocturnal LF/HF and HRR.

Discussion

HRV

There are few studies investigating the effects of AT on HRV and results of these studies are not consistent. Mitani et al. [17] indicated a beneficial effect of 2 month AT intervention on sympathetic (LF/HF) and parasympathetic (HF/total power) nervous activity changes, and Miu et al. [18], in their experimental study, presented a remarkable increase of parasympathetic activities (HF). In contrast, both Lim et al. [35] and Kim et al. [38] noted no significant changes in HRV by 8 week AT intervention. These inconsistent of the results might be partially due to a considerable difference in the contents or length of AT applied as intervention and in the parameters used for assessment of HRV. In addition, inter-individual differences even in resting ANS activities and their response to AT might be so variable that the effects of AT could have been concealed. In the present study, however, nocturnal LF/HF which is an index of cardiac sympathetic activity of HRV [5,32] was significantly reduced in the AT group.

Many studies have indicated that obesity might lead to cardiac diseases or other metabolic diseases [1-3] through increase of cardiac sympathetic activity and the predominance of sympathetic tone during sleep might facilitate the onset of cardiovascular accidents. In addition, suppressive of sympathetic tone is thought to improve cardiac remodeling, which is relevance in obesity and associated with progressions of cardiovascular disease as well as heart failure [4]. AT might therefore have beneficial effects on eliminating the causal relationship between obesity and cardiovascular diseases. In the study, however, lowering effects on LF/HF was observed only during sleep at night but not during the day because LF/HF might be highly variable depending on the daily activities of the subject.

HRR

In AT group, HRR after exercise test was significantly increased. Previous studies have shown that weight loss [11,12], regular aerobic training [39], treatment of SAS [24] and intake of omega-3 fatty acid [40] could elevate HRR. However, the present study is the first report indicating the effects of AT on HRR. HRR is considered to express complex autonomic functions, which is predominantly derived from

parasympathetic reactivation with reducing sympathetic activity, and is an important predictor of type 2 diabetes mellitus [41] and the prognosis of cardiovascular diseases [6]. The results of HRR, an autonomic nervous function after exercise cessation, also suggest that AT intervention may reduce cardiac risk in obesity.

Stress and sleep condition

It has been reported that AT could improve psychological or mental strain among subjects with mental disorders or in high-stress situations [42]. In this study, the Confusion-Bewilderment score of POMS was improved by AT (Table 2b). However, no remarkable effects were observed on the other scores such as Depression-Dejection or Tension-Anxiety scores. These results suggest that daily AT training could not induce an improvement in all aspects of psychological distress in healthy subjects.

Although some studies have indicated an effectiveness of AT in subjects with insomnia [43], we did not observe any effects on sleep conditions assessed by PSQI in our study. However, sleep conditions were assessed by a self-report questionnaire (PSQI). Further studies using objective physiological parameters for evaluating sleep condition are needed.

Mediation analysis

Lucini et al. [19] reported that behavioral and relaxation interventions improved ANS dysfunction by improving high-stress condition in subjects with stressful situations. In their study, stress conditions were considered as mediators of ANS dysfunctions. In the present study, mediation analysis revealed that reduced nocturnal LF/HF and increased HRR were not mediated by improvement of any psychological or mental conditions. From these results, it is likely that AT directly improved the obese-induced ANS dysfunction. The mental stress mediated ANS dysfunction might be exaggerated by obesity [44], which in turn, increases cardiovascular risk through accelerating cardiovascular reactivity to mental stress [45,46]. In addition, sympathetic activation may contribute to the development of future abdominal adiposity [45]. The exact mechanisms of AT benefit requires further clarification.

In the present study, AT had no significant effects on sleep conditions. There were also no correlations between changes of ANS and that of sleep conditions.

Limitation

Our study has several limitations. First, the sample size of the present study (n=40) was smaller than the estimated size due to subject omission from technical errors in measurement. In addition, as the inter-individual differences in cardiac ANS activities were originally considerable, it would be difficult to detect statistically significant differences in the changes of ANS activities between the two groups. Second, our sample was Japanese obese/overweight male worker. There are some differences in the association of obesity with cardiac or metabolic risk between Western countries and Japanese people [47]. We also did not assess effects of AT on ANS in non-obese or female people. Thus, our results and interpretations must be carefully generalization. Third, although daily AT practice was required for subjects of the AT group, we could not monitor their exact implementation status in the daily life. Therefore, this may results in large differences in the effects of AT performance among the subjects. Fourth, we obtained a significant difference in cardiac autonomic nervous activity only during the night. However, subjects were not screened for sleep disorders through medical examinations but through a self-reported questionnaire. As nocturnal HRV and HRR are affected by sleep disorders such as insomnia [43] or SAS [24], which are prevalent among working-age Japanese obese men, the possibility that the results were confounded by a variety of sleep disorders among the subjects cannot be excluded. Finally, we did not assess ANS activity, especially sympathetic activity, using more reliable biochemical or electrophysiological indices of sympathetic activity. Grassi et al. indicated that the most reliable ways to measure sympathetic activity was direct recordings of sympathetic nerve traffic via microneurography and noradrenaline radiotracer methods [48].

Conclusion

A three month AT intervention reduced cardiac sympathetic activity during sleep, and increased parasympathetic activity in HRR in Japanese obese/overweight male workers. These results suggest the beneficial effects of AT on obesity-related cardiovascular or metabolic conditions.

Acknowledgments

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Conflict of Interest

The authors declare that they have no conflict of interest.

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