33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Effectiveness of interval training compared with endurance training in cardiac rehabilitation

Satoru Hanada, Masaki Sekine, Member, IEEE, Toshiyo Tamura, Senior Member, IEEE, Tomokazu Shinchi, and Toshiro Fujimoto

***Abstract*—Anaerobic endurance training (AET) can improve sympathomimetic hyperactivity, and anaerobic interval training (AIT) is recommended for patients who cannot exercise due to exertional breathlessness and leg fatigue. However, the difference in sympathetic nerve activation (SNA) and parasympathetic nerve activation (PNA) during AIT and AET is unclear. The aim of this study is to investigate the differences between endurance and interval trainings. We studied three patients (63-73 years) assigned to AIT which exercise/pause phase is 60/120 seconds (AIT120) and AET of 10 minutes duration. Systolic blood pressure, heart rate (HR), and rate pressure product (as an index of SNA) and oxygen uptake, tidal volume, respiratory rate, and minute ventilation were measured. As a result, these parameters in AET were increased compared with those of AIT120 among the subjects. While, high frequency component of frequency distribution in HR (HF) in AET was decrease compared with that in AIT120 among subject. We concluded that AIT inhibited SNA more effectively compared with AET and AIT may be safe for cardiac rehabilitation.**

I. INTRODUCTION

In Japan, approximately 20% of the whole inpatient are diagnose as cardiovascular disease. Furthermore the population ratio of elderly people over 65 years old is more than 20%. In future, the ratio of cardiovascular disease will increase more because of progressively aged population. One characteristic of cardiovascular disease is sympathomimetic hyperactivity included exertional breathlessness and fatiguability. An anaerobic endurance training (AET) is recommended to prevent sympathomimetic hyperactivity. However, elderly patients quit their exercise during in the middle of AET. As a result, exercise tolerance activities are getting worse. Therefore, it is necessary for these patients to prevent deterioration in progression of disease and onset of disease by exercising as much as possible. These patients may be performed continuous training by introducing a new training method of anaerobic interval training (AIT). There are a few reports to monitor physiological parameters such as systolic blood pressure (SBP), heart rate (HR), oxygen uptake (Vo_2) and minute ventilation (V_E) during AIT and AET. Meyer et al have reported that three interval exercise modes with different ratios of work/ recovery phases (30/60 s, 15/60 s and 10/60 s) and different work rates were compared during cycle ergometer exercise in heart failure patients [1]. Work rate for the three interval modes was 50% (30/60 s), 70% (15/60 s), 80% (10/60 s) of the maximum achieved during a steep ramp test (increments of 25 W/10 s) corresponding to 71,98 and 111 watts on average. Their results showed that SBP and HR in mode of 10/60s significantly increased. However, Vo_2 and V_E at all three interval modes and SBP and HR at those modes except 10/60s did not increase significantly during the exercise. Watanabe et al have reported that there were no significant differences in work period between exercise with four minutes work period and two minutes resting period and one with two minutes work period and one minute resting period [2]. While, Matsumoto et al have reported that changes in SBP, HR, and high frequency component of R-R intervals (HF) by AET for six minutes showed that SBP and HR the indices as index of a sympathetic nerve activation (SNA) increased and HF as index of a parasympathetic nerve activation (PNA) decreased during AET [3]. Thus, these studies revealed that SNA in each training increased by exercising. However, it is not revealed the difference in SNA and PNA during AIT and AET. The presence of depressed vagal reflexes and enhanced sympathetic activation is associated with a greater risk for life-threatening arrhythmias during myocardial ischemia. It is important to clarify the changes in SNA and PNA during each training for patients with cardiovascular disease because exercise with excess high blood pressure may cause further sympathicotonia. Therefore, we performed an experimental study for healthy men to reveal the difference in SNA and PNA during AIT and AET. This study suggested that AIT inhibited SNA compared with AET in healthy men, and AIT might be possible for cardiovascular patients safety.

In this study, we performed clinical study for cardiovascular patients to reveal whether our suggestion is correct.

II. METHOD

A. Study population

The study population consisted of three cardiovascular patients, who were referred to our rehabilitation laboratory by their clinicians, in order to participate at the rehabilitation program (TABLE1). All patients were taken a beta blocker,

Satoru Hanada, Masaki sekine, and Toshiyo Tamura are with the Department of Medical System Engineering, Faculty of Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba, 263-8522, Japan. (hands_54@graduate.chiba-u.jp).

Satoru Hanada, and Tomokazu Shinchi, are with the Fujimoto Central Hospital, 3584-1 Midarebashi, Kitakawauchi-cho, Miyazaki, 880-0941, Japan. (miya-heart-reha@fujimoto.or.jp).

Toshiro Fujimoto is with The Fujimoto Hayasuzu Hospital, 17-1, Hayasuzu-cho, Miyazaki, 885-0055, Japan. (hisho@fujimoto.or.jp).

and two in three patients also were taken an antihypertensive. Exclusion criteria were female gender, contraindications to cardiopulmonary exercise testing (CPX), insulin-dependent diabetes, pericarditis, peripheral neuropathy, orthopedic or neurological limitation.

B. Exercise prescription

All subjects performed a symptom-limited, ramp-incremental CPX on a cycle ergometer (model Well Bike BE-360, Fukuda Denshi, Tokyo, Japan) to determine an anaerobic threshold (AT) before AIT and AET. AT was determined by V-slope technique [4]. Vo_2 was obtained at the AT and peak exercise. HR and work rate were obtained at the AT. The Peak Vo_2 was set when subjects could not maintain cycling at 50 rpm. Before AIT and AET, all subjects kept resting condition with supine position in a quiet room which was set to temperature 22 to 25 degrees and humidity 40% to 60%, and were asked to relax and to avoid sleeping or talking.

AIT performed into 10 bouts of the exercise with pause phase of 120 seconds (AIT120). The length of exercise phase in AIT120 was decided 1 minute. Training intensity was set work rate at AT. AET performed constant intensity of 10 minutes. All trainings took a rest of three minutes on a cycle ergometer (model Well Bike BE-250, Fukuda Denshi, Tokyo, Japan) when before and after each trainings. All subjects were instructed not pedaling for rest or pause phases. All measurements were recorded for three minutes at rest before start, throughout training, and after training rest. Gas samples were collected on a breath by breath basis. The results obtained for Vo_2, tidal volume (V_T), respiratory rate (RR), and V_E were sampled every five seconds as measurement indices of respiratory response. SBP was measured every minute by automatic manometer (model STBP-780, Nihon Colin, Aichi, Japan). HR with chest bipolar lead was monitored continuously on an ECG telemeter (model multi telemeter system WEB-5000, Nihon Kohden, Tokyo, Japan). Frequency was analyzed using Fast Fourier Transform (FFT) from R-R interval. The power spectral density was calculated by applying the FFT to overlapping segments of the resampled date and by averaging the spectral results. The FFT was calculated by 256 points and half overlap with a Hann window. About analysis of frequency domain variable, 0.15-0.4 Hz was defined as high frequency (HF), and measurement index of PNA. SBP, and HR were used as indices of SNA. AIT120 and AET were performed random order. The interval among CPX, AIT120, and AET was approximately one day. The all subjects were asked to refrain from eating, drinking, and smoking for two hours before.

The protocol of this study was approved by the Ethics Committee of the University of Chiba, and the Fujimoto Central Hospital. Informed consents were obtained from all subjects at beginning of this study.

TABLE 1
BASELINE CHARACTERISTICS OF CARDIOVASUCULAR PATIENTS

Subject	1	2	3
Age [years]	63	73	73
Sex	Male	Male	Male
Height [cm]	162.0	161.9	160.0
Weight [kg]	50.0	62.2	62.1
Disease	AVR	CABG	AMI
EF [%]	52.0	80.1	44.0
Training intensity [W]	33	23	40
Vo_2 at AT [l/min/kg]	0.49	0.58	0.75
HR at AT [beat/min]	84	95	64
Peak Vo_2 [l/min/kg]	0.66	0.64	0.88

AVR = aortic valve replacement, CABG = coronary artery bypass grafting, AMI= acute myocardial infraction, EF=ejection fraction, Vo_2= oxygen uptake, AT=anaerobic threshold, and HR= heart rate.

C. Date processing method

The parameters of indices from all training sessions excluding SBP were calculated using the mean of the measurements taken every minute. In AIT120, the mean of each index was defined as the mean of measurements taken every minute during the 1st to 10th bout for exercise phase. In AET, the mean of each index was defined as the mean of the measurements taken every minute during each of the 10 bouts of continuous exercise.

III. RESULTS

All subjects could be measured without dropping out CPX, AIT120 and AET. The value of training intensity, Vo_2 at AT, HR at AT, and peak Vo_2 with each subject that subject. 1 was 33W, 0.49 L/min, 84bpm, and 0.66 L/min, subject. 2 was 23W, 0.58 L/min, 95bpm, and 0.64 L/min, and subject.3 was 40W, 0.75 L/min, 64bpm, and 0.88 L/min. The TABLE.1 shows the values of these parameters with each subject. The increase rate of from 1st to 10th exercise bout of all parameters in each training are shown in TABLE.2. All parameters at 10th exercise bout in each training except HF of AET were increased compared with those in 1st bout. In contrast, HF in AET at 10th bout was decreased compared with 1st bout. In comparison to AET, the rate of increase in AIT120 except HF were decreased. The typical SBP, HR, RR, and HF are shown in Figs. 1 to 4. SBP, HR in AET were increased slightly at the onset of exercise and reached a plateau by 4th min. Those parameters in AIT120 also were increased at the onset of exercise but reached a plateau by 2nd bout. RR in both training remained constant from 1st to 10th bout. HF in AET was decreased at the onset of exercise. In contrast, that of AIT120 was increased at 2nd to 3rd bout, but gradually decreased afterwards.

TABLE 2
RATE OF INCREASE FROM 1ST TO 10TH EXERCISE BOUT OF PARAMETERS IN EACH TRAINING

Subject		1	2	3
Parameter	Training			
SBP [%]	AIT120	6.2	7.7	0.7
	AET	33.6	27.4	23.8
HR [%]	AIT120	4.5	6.3	7.7
	AET	35.2	15.0	13.3
Vo_2 [%]	AIT120	16.4	20.4	12.8
	AET	86.4	71.4	79.9
RR [%]	AIT120	7.9	5.7	6.8
	AET	11.4	12.0	0.4
V_T [%]	AIT120	16.0	19.4	11.7
	AET	56.8	33.9	67.9
V_E [%]	AIT120	25.6	25.8	16.9
	AET	75.6	49.9	79.5
HF [%]	AIT120	42.5	1.7	29.1
	AET	-69.7	-57.6	-89.0

SBP = systolic blood pressure, HR = heart rate, Vo_2 = oxygen uptake, RR = respiratory rate, V_T = tidal volume, V_E = minute ventilation, HF = high frequency, AIT = anaerobic interval training, and AET = anaerobic endurance training.

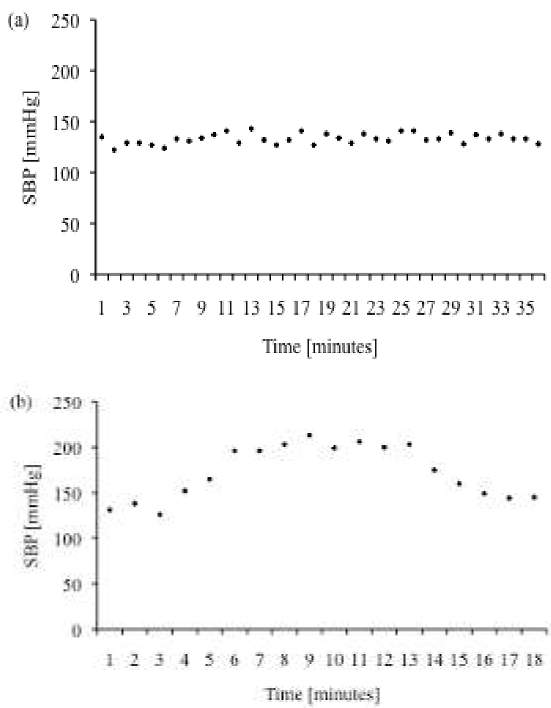

Fig.1. A Typical example of SBP recordings. a: AIT120, b: AET.

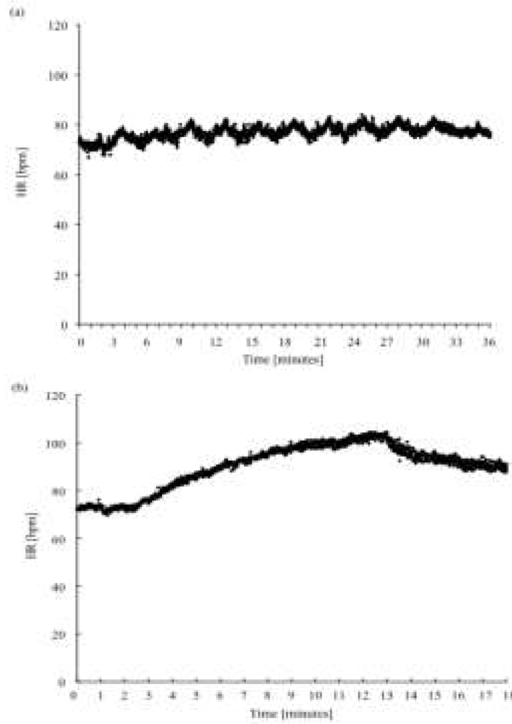

Fig.2. A Typical example of HR recordings. a: AIT120, b: AET.

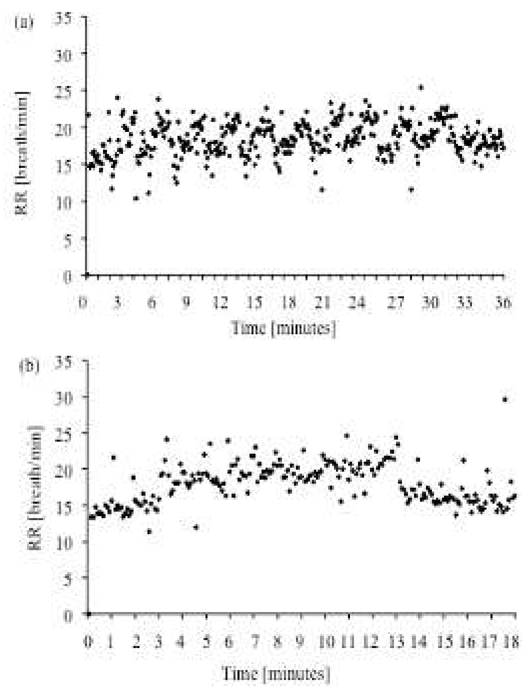

Fig.3. A Typical example of RR recordings.. a: AIT120, b: AET.

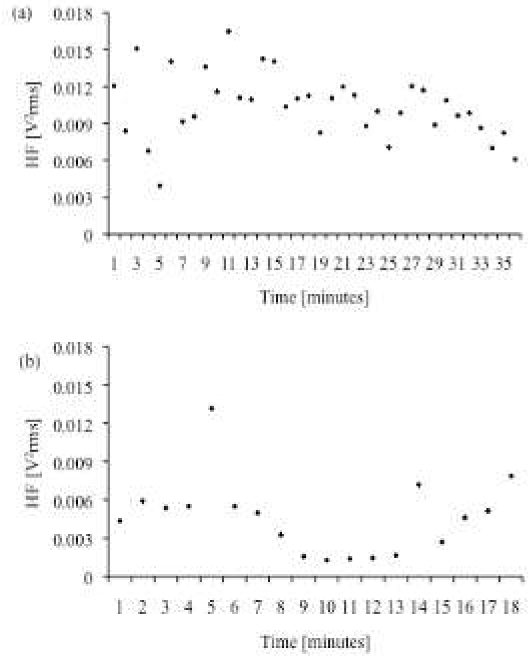

Fig.4. A Typical example of HF recordings . a: AIT120, b: AET.

We have only three subjects and difficult to get statistical significance, but the tendency of the change in these parameters can be observed among the subject.

IV. Discussion

Our results suggest that AET induced a tendency of higher increase rate in SNA and respiratory response but lower decrease rate in PNA compared with AITI120. These results were the same as our previous study. In generally, HR and respiratory responses were correlated with training intensity. However, our results in this study were different, despite the training intensity was the same. These results were probably caused by differences in exercise time per bout. The exercise time of AIT120 was 1 minute per one bout, whereas that of AET was 10 minutes.

At the 1st bout in AIT120, HR and respiratory responses were increased as same as those in AET. However, those in AIT120 were decreased because inserting pause phase after exercise phase. Therefore, those in AIT120 at 10th bout were not increased compared with 1st bout. In contrast, those in AET were increased and reached a new steady state condition by 4th bout even in keeping exercise. From these results, the increase rate in those of AIT120 were smaller compared with those of AET.

On comparison of HF in AIT120 and AET, all subject of HF in AET have a tendency to decrease on exercising. In contrast, HF in AIT120 maintains high value in exercise phase It seemed those results were caused by inserting pause phase as same as the results in HR and respiratory response. During pause phase, parasympathetic nerve activity was dominant and high compared with exercise phase. Then during exercise phase, PNA was decreased but was not critically dropped. Thus the HF during exercise phase showed relatively high values. Furthermore, our results were consistent with the report that the amplitude of the HF gradient showed a negative correlation with RR [5].

These results in this study suggested that AIT could perform safety compared with AET because increase rate of SNA was small. Furthermore, there were correlation between V_E and breathlessness. From these results, AIT is recommended to introduce for cardiovascular patients with low physical strength when they start exercise in the cardiac rehabilitation.

V. Conclusion

Our result in this study indicated that SNA during AIT was more effectively inhibited compared with AET in cardiovascular patients. AIT protocol is safe and it has not so strong limitation. Subject may perform CPX but CPX is not obligatory Without CPX, we can use the literature values for cardiovascular patients.

In this study we have performed only three patients and we need to more experiments for concrete conclusion.

References

[1] Meyer K, Samak M, Schwaibold S, Hajric R, Lehmann M, EBfeldt D, and Roskamm H. “Physical responses to different modes of interval exercise in patients with heart failure: application to exercise training.” *Eur Heart Journal,* vol. 17, pp. 1040 -1047, 1996.

[2] Watanabe S, Yamada S, Yamasaki H, and Maeda H. “Investigation of Interval training mode for Application in patients with Myocardial Infraction.” *Japanese Physical Therapy Association* vol. 17 no.4, pp371–375, 1990. (in Japanese)

[3] Matsumoto T, Matsunaga A, Hara M, Saitoh M, Yonezawa R, Ishii A, Kutsuna T, Yamamoto K, and Masuda T. “Effects of the breathing mode characterized by prolonged expiration on respiratory and cardiovascular responses and autonomic nervous activity during the exercise.” *Jpn J. Phys. Fitness Sports Med*. vol.57, pp 315–326, 2008. (in Japanese)

[4] M’Bouh S, Bellmont S, Lampert E, Epailly E, Zoll J, N’Guessan B, Ribera F, Geny B, Oyono S, Arnold P, Lonsdorfer J, and Mettauer B. “An impaired cardiodynamic phase contribute to abnormal Vo_2 kinetics at exercise onset in both congestive heart failure and heart transplant patients but results from differing mechanisms.” *Transplant Proc* vol.33, pp3543–3545, 2001.

[5] Grossman P, Kollai M.”Respiratory sinus arrhythmia, cardiac vagal tone, and respiration: Within- and between-individual relations.” *Psychophysiology*. 30, pp.486-195, 1993.