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その他（別言語等）のタイトル	ヒトの心臓血管系の機能障害における自己コントロールの試み
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journal or publication title	Memoirs of the Muroran Institute of Technology
volume	49
page range	1-7
year	1999-11-30
URL	http://hdl.handle.net/10258/148

Mem. Muroran Inst. Tech.,49(1999)1~7

Self Control of Cardiovascular Function using Biofeedback Method

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(Accepted 31 August 1999)

It was suggested that human subjects were able to regulate own HR with an assistance of apparatus in several kinds of cardiovascular dysfunctions, such as sinus tachycardia when the cardiac conduction system was within normal limits. With regards to the mechanism of HR BFT, subjects seem to use variety of strategies as influences of central nervous function, endocrine system as plasma catecholamines (specially epinephrine), psychological cues and cognition.

Keywords: biofeedback training, biofeedback control, self control, heart rate, tachycardia, bradycardia

1 INTRODUCTION

Self-control of physical and psychological function has been studied since early 1960 with development of electronics sciences and was named Biofeedback control or Biofeedback treatment (BFT). Study or biofeedback control in heart rate (HR) is one of the earliest and has been most profoundly discussed.

Although self-control of HR has been reported early in 1970, clinical application has not been advanced. One of main reason is pharmacological treatment is more influential from standpoints of effectiveness and cost performance. We introduce human uses of HR-BFT such as HR slowing in sinus tachycardia, paroxysmal tachycardia and HR speeding in sinus bradycardia. The main part of this presentation is clinical interventions of cardiovascular dysfunctions and analytical approach to the mechanism of HR-BFT.

2 APPARATUS

This apparatus for HR-BFT was developed in cooperation with Applied Institute if Electricity of Hokkaido University[1,2]. The block diagram of the apparatus is shown in Fig. 1. The system of this apparatus is composed of three parts;

A) The first part has two biofeedback monitoring systems; the first monitoring heart beat by light and/or sound, and giving feedback of integrated HR (beats per min, bpm) by digitalised figures.

B) The second part of the unit gives exteroceptive sound or light stimuli of 60 Hz audiovisually; the characteristic of exteroceptive sound will be discussed later. this part is used only in cases who cannot control their HR with ordinary BF method. That is, if they are not good in HR-BFT, they are given light and/or sound emission of 60 Hz, 62dB SPL in bursts while doing biofeedback training. Some of the patients become better in HR-BFT by this method. The reason why this is often helpful in BF control has not been clarified yet.

C) The third part is for operant BFT. This takes the averaged HR of the pre-test period, then gives the results of HR-BFT in each trial blocks. When a trial exceeds the average HR of the pre-test period, the red lamp lights, and when another trial goes under the average, the green lamp lights.

3 PROCEDURE

Four kinds of strategies are used in our HR-BFT; that is, 1) Simple or ordinary HR-BFT. 2) HR-BFT with exteroceptive sound stimuli(60 bpm) which is pure tone burst of 60Hz, 65 dB SPL. The subjects for this method was prescreened when the tachycardic subjects could not decrease their HR 5% from mean HR with ordinary BF method within first 5 minutes. Then, they were given light and/or sound

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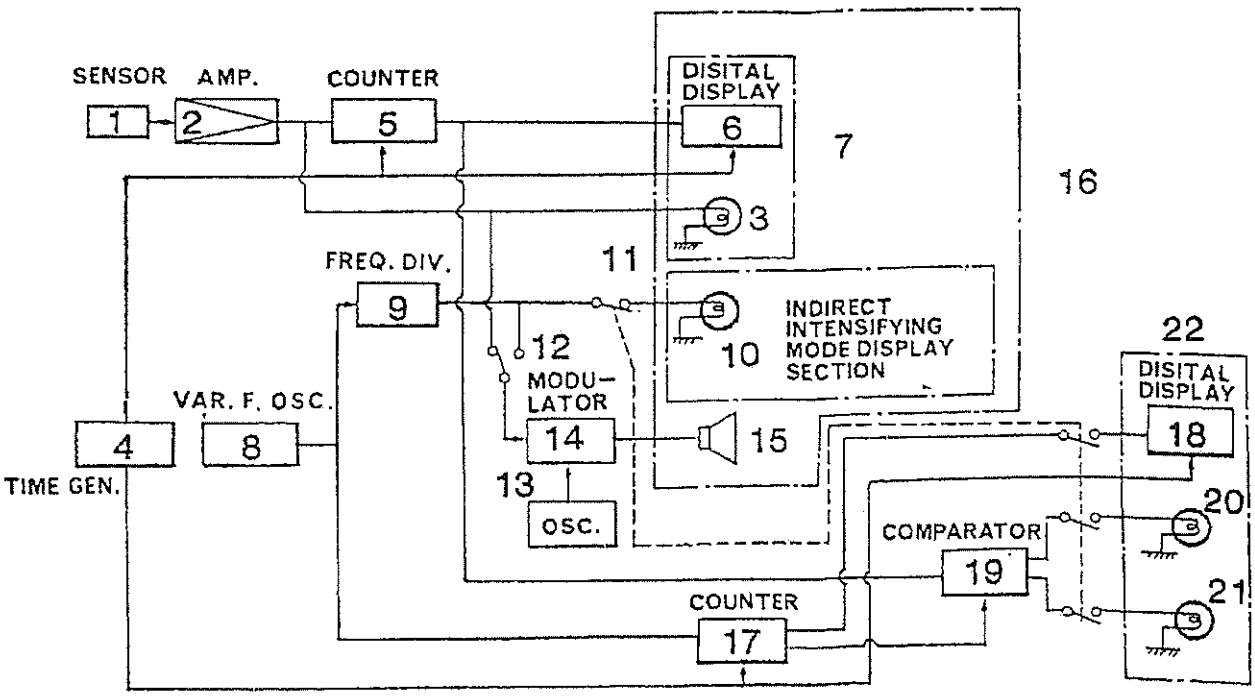

Fig. 1. Block Diagram.

emission of 60 Hz, 62dB SPL in bursts while doing BFT. 3) Operant BFT of HR speeding/slowing, 4) Stress loaded HR BFT. This BFT intends to learn how to coperealize the relationship between own HR and HR increasing factors, that is, the therapists prepare several situations for patients, 1) to realize what factors increase HR, and then 2) cope with such factors by trial and error, and 3) finnaly to be desensitized against these factors.

4 APPLICATIONS

First, we applied BF technique to patients suffering from sinus tachycardia. In normal healthy peoples, HR ranges between 60 and 100bpm. When HR is over 100bpm, it is named tachycardia, and if HR is slower than 60bpm, it is named bradycardia. In this presentation, all cases of sinus tachycardia and sinus bradycardia, all subjects of sinus tachycardia and sinus bradycardia were within normal limit in the conduction system by ECG examination and if the subjects showed abnormal, they were excluded from this program and referred to cardiologists.

First, we applied HR-BFT to patients who suffered from tachycardic complaints. After we concluded that HR-BFT seemed helpful, we developed a series of studies on sinus tachycardia, mild degree of arrhythmias, vascular tonus abnormalities, hypertension, sinus bradycardia, rehabilitation of organic heart diseases and those in the aged.

4.1 HR-BFT in sinus tachycardia

1) Ordinary HR-BFT and Joint Use of exteroceptive sound stimuli of 60Hz Although Engel and other psychophysiologists showed successful self-control of HR in various kinds of tachycardia as sinus tachycardia, paroxysmal tachycardia and atrial fibrillation in early 1970, this method does not become popular because of technical difficulty, unstable effectiveness compared with pharmacological treatments and cost performance except psychophysiological research. In our presentation, 37 % of sinus tachycardic patients were able to decrease their HR with ordinary BFT in the first session. With repeated training, sucessful rate increased.

To raise the success rate in BFT of HR slowing in sinus tachycardic patients, one is joint use of autogenic training that was developed by Shurtz for psychophysiologic relaxation. However, as we had already experienced that exteroceptive sound stimuli of busting type(60Hz) was HR decreasing in sinus tachycardic patients, we studied whether exteroceptive sound stimuli of 60Hz has any effect on BFT of HR.

Subjects: 56 subjects in which 22 were male and 34 were female with age of 21-71.

Procedure: No instruction was given to decrease HR, they were just said " let's examine your HR". After 5 minutes of the pre-test HR were taken, patients did HR-BFT and they were classified into two groups according to the

results of BF ability; 1)one group which could control their HR kept HR-BFT as it was, and 2) another group which could not control their HR till then were given exteroceptive sound stimuli of pure tone burst of 60Hz SPL during HR-BFT.

Results:

1) Effect of HR decreasing with BFT and exteroceptive sound stimuli(60Hz). The results showed that 21 subjects(37.5%) out of 56 subjects, were able to descrease HR with BFT. When the rests, 35 subjects practised HR-BFT with exteroceptive sound stimuli of pure tone burst of 60Hz SPL, 29 subjects(82.9%) could decrease HR consequently. So in total, 50 out of 56 subjects(89.3%) were able to decrease HR with BF method. It is suggested that exteroceptive sound stimuli has special influence on self-control of HR decreasing in sinus tachycardia with chi-square test(Chi-square test; $P < 0.05$). The exteroceptive sound stimuli seems helpful in BFT of HR decrease and we concluded this complementary method is avalable in HR-BFT. The grade of HR decrease(%) is shown in Table 1.

4.2 Relationship in Mental Condition and Self-Control of HR

Next we examined patients' ability of HR-biofeeedback training from aspect of psychological conditions[3]. That is, we examined how emotional instability as anxiety and depression influence on biofeedback control of HR. The first is to see if there are any differences between patients with normal mental state and neurotic traits or depression. For evaluation of neurotic traits, Hukamachi's Questionnaire was used. This is translated and arranged from Cornell Medical Index (CMI) and has been used most widely in Japan. In Hukamachi's classification, it is possible to classify the subjects into 4 sub-groups according to the grade of neurotic traits. The subjects with neurotic traits belong the third and fourth sub-groups, while non neurotic subjects are located in the first and second sub-groups.

With regards to depression, The patients with sinus tachycardia were examined with Masked depression questionnaire. This is modified in Toho University from Zung depression scale that has most globally used for evaluation of depression.

4.2.1 Neurotic traits. The whole patients were divided into two distinct groups; those with neurotic traits and those without. As shown in Table 2, the non-neurotic group was better in the self-control of HR with biofeedback method, however, the neurotic group was not so(Chi-square test; 11.96, $P < 0.05$). It is suggested that neurotic condition is adverse in self-control of HR-BFT.

4.2.2 Depression. The patients were classified into two groups; a sub-group with depression and another with non-depression. The results indicated that non-depression sub-group was able to perform better in the self-control of HR with biofeedback method than the sub-group with depression (Chi-square test; 9.64, $P < 0.05$). Clearly enough, emotional state of patients is important factors when using HR-BFT. In patients who responded poorly to HR BFT, the SL-60 seemed to improve the BF ability.

4.2.3 Tachycardia provoking factors. The patients reported that following things were provocative triggers for tachycardia;

1)anger, fear, shock, sorrow & excitement(including joy),

2)pain & being touched,

3)tobacco, coffee & alcohol,

4)big noise, foot sound, siren & buzzer & earthquake,

5)stress related with communications (family problems, sudden visitor), bereavement, troubles in worksite, money problem, & drive.

So we tried to classify HR-BFT into two categories, that is, 1) direct BFT, and 2) indirect HR-BFT. Direct HR-BFT focus the BFT control of authentic autonomic nervous function from basic standpoint and is mandatory for obtaining results in basic studies. Operant BFT of HR speeding or slowing is one of examples. While indirect HR BFT intends to control secondary and interfering factors which provoked sinus tachycardia or arrythmias as excessive reaction. When the subjects noticed such relationship between above-mentioned things and HR increase or tachycardia, the subjects can prepare themselves for these factors in advance. Recently this type of BFT is called BF assisted cognitive treatment. Next stress loaded HR-BFT was designed to treat reactive HR increase triggered by tachycardia provoking factors.

4.3 Desensitization HR BFT - control of disturbing factors

This mode of HR-BFT[4] means management of stress with HR BFT . In this HR BFT, we practiced stress interview with patients to desensitize their anxiety and phobia during HR BFT.

Subjects:

Forty subjects of functional sinus tachycardia were divided into two groups; The control group is 16 subjects, 7 male and 9 female, with a mean age of 38.6(18-59 yrs old.) received ordinary HR-BFT. The HR-BFT with desensitization training consists of 24 subjects, 11 male and 13 female, with a mean age of 40.3(19-57 yrs old).

Table 1. Numbers of subjects who could decrease their HR.

	3.0-4.9%	5.0-9.9%	10.0-14.9%	15.0-19.9%	20.0-24.9%	25.0-29.9%	> 30%
HR-BFT	2	9	6	4	1	0	0
Desensitized HR-BFT	5	11	6	1	2	1	3

Table 2. The aversive influence of neurotic traits on HR-BFT.

	Non-neurotic group	Neurotic trait group
Patients controlled HR with BFT	53.3(%)	14.6 (%)
Patients controlled HR with BFT & exteroceptive stimuli	26.7	75.4
Patients could not control HR	20.0	10.0

Table 3. The aversive influence of depression on HR-BFT.

	Non-depression group	Depression group
Patients controlled HR with BFT	65.2(%)	20.6 (%)
Patients controlled HR with BFT & exteroceptive stimuli	29.6	69.0
Patients could not control HR	10.2	10.3

Table 4.

	2 weeks	3 months	6 months
Ordinary HR-BFT	68.8 ± 5.4% (NS)	43.8 ± 6.2% ($P < 0.05$)	31.3 ± 5.4% ($P < 0.05$)
Desensitization HR-BFT	75.0 ± 3.7%	64.0 ± 4.8%	54.2 ± 5.1%

Table 5.

	Lying	Sitting	DST-HR-BFT	BFT of HR slowing
HR	71.1 ± 18.2	74.5 ± 18.5	76.9 ± 17.4	75.6 ± 17.0
SBP	104.1 ± 10.9	107.1 ± 15.8	106.9 ± 15.2	111.5 ± 14.4
DBP	60.3 ± 10.4	69.3 ± 8.4*	68.8 ± 8.0	72.2 ± 8.1
RPP	7512.4 ± 2036.5	8078.4 ± 2767.1	8245.7 ± 2569.1	8246.0 ± 2205.1
plasma E	67.8 ± 33.4	123.1 ± 78.5**	104.6 ± 79.9	69.8 ± 44.1*
plasma NE	358.8 ± 212.7	584.8 ± 310.5***	534.4 ± 301.5	537.8 ± 251.8

* $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$

Procedure:
Ordinary HR-BFT: Subjects were asked to take rest for 10 minutes, to watch their heart beats on a HR biofeedback monitor without moving or altering their breathing pattern, and to record their HR on paper every minutes with minimum movement for 40 minutes after HR baseline was recorded.
Desensitization HR BFT: During preliminary interview, stressful topics and items, which provoked tachycardia were selected from subjects and Wolpe's Fear Survry Schedule. They were suggested to speak about their concerns, such as diseases or tachycardia provoking factors or to answer questions therapist asked. Mean number of session was 4.8.
Results:
A) Ordinary HR BFT group:
14 out of 16 subjects decreased their HR between the first and last session. HR was 87.5 ± 10.8 bpm in the first session and 79.7 ± 11.5 bpm in the last session ($P < 0.05$).
B) Desensitization HR BFT:
22 out of 24 subjects decreased their HR between the first and last session. HR was 84.6 ± 11.5 bpm in the first session and 70.6 ± 7.0 bpm in the last session ($P < 0.05$). Both group was compared in terms of the numbers of sessions required to attain a normal and stable HR(60-89 bpm). Ordinary HR-BFT group were 3.9 ± 0.6 sessions, and Desensitization HR-BFT group was 2.7 ± 0.3 session ($P < 0.05$). The maintenance period was shown in Table 4.

Six months follow-up showed that there was significant difference in the maintenance rate of the effectiveness at 3 months and 6 months ($P < 0.05$). It took less numbers of sessions for tachycardic patients to return to normal range of HR in group of HR-BFT with desensitization method than ordinary HR-BFT group, and follow-up results was better in the same group.

Wolpe's Fear Survey Schedule: Cognitive aspects of Desensiitization HR-BFT was examined Wolpe's Fear Survey Schedule(FSS). This was developed by Y. Wolpe to evaluate subjective perception of phobic and stressful events by 5 graded rating. Sixteen out of 24 subjects were examined before and after HR-BFT with desensitization method. Eleven out of 16 subjects decreased self rating points of phobic and discomfortable items. The rating points of Wolpe's FSS revealed 142.7 ± 72.4 before HR-BFT, and 116.9 ± 58.9 at the end of this program ($P < 0.05$). Numbers of items in high score shifted to lower one by Chi-square test ($P < 0.05$, F=11.876, DF= 4). So this type of training seemed to be helpful for desensitization.

4.4 Gender Difference in HR-BFT

Development of 24 hr Holter monitoring of HR revealed that female subjects were higher in HR, while male subjects were higher in blood pressure. We examined this phenomena and whether there is any difference in the ability of biofeedback control of HR[5].
Subjects: 78 subjects (40 male, 38 female) practiced self-control trial with HR-BFT slowing. This group was uniform in functional sinus tachycardia.
Procedure: apparatus and procedure as same as afore-mentioned.
Results: The results were summarized as follows; 1) The mean HR before HR-BFT showed 84.9 ± 1.6 bpm in female subjects, and 78.7 ± 1.9 bpm ($P < 0.05$). 2) The biofeedback ability was examined even after these subjects were classified to 4 ranks divided by 10 bpm, such as <69bpm, 70-84bpm, 85-99bpm and >100bpm. There was no gender difference in the ability of biofeedback control of HR slowing.
Discussion: The main reason for different results between above-mentioned two methods was that the subjects were not uniform in the first study in which this group of tachycardic patients were mixed with functional sinus tachycardia and those due to organic diseases. With regards to the biofeedback ability of HR slowing, The second results were consistent with Young & Blanchard's results[6]. Several reports dealt with gender difference in cardiovascular function. Evans, A.D.[7] examined the cardiovascular reaction to foot cold pressor task. They noticed that women, relative to men, had higher HR responses to the cold pressor while men exhibited higher systolic and diastolic blood pressure level in response to the task. Thailer[8] reported that the role of anger and hostility to blood presure appeared different in male and female. Bohondo[9] suggested that there was gender difference between style of anger expression, and systolic blood pressure and HR reactivity to a competitively challenging task. Girdler[10] suggested that the race and gender difference in cardiovascular responses depend at least partly on a function of beta-receptor activity.

4.5 HR-BFT of sinus bradycardia

Present study was intended whether subjects with sinus bradycardia without conduction disorders were able to speed their HR with BFT[10], and whether aged subjects were also able to increase HR as young and middle aged subjects[11].

4.5.1 BFT of HR speeding in the bradycardia of mild criteria (HR; <60 bpm).
Subjects: 35 subjects of sinus bradycardia without conduction disorders are divided into 2 groups by age. The subjects' HR were less than 60 bpm, the criteria of sinus bradycardia is not strict one as WHO criteria. The first group is the young and middle aged subjects with age of 16-47, consisting of 20, 13 male and 7 female. The second is the aged group consisting

of 15 subjects (8 male and 7 female) between 60-74 years old.
Procedure: Before BFT sessions, subjects are asked to rest for 5 minutes, to try to increase their HR without moving or altering their breathing pattern. The goal of HR increase is up to the normal sinus rhythm between 60-89 bpm. The training consists of 6 subsessions of 5 one-minute session trial blocks each after 2 one minute pretest value of HR are taken, and with 3 minutes rest between these subsessions. They had 3 to 10 sessions in trial, specially at the mean of 2.5 sessions in the 16-47 years old group and 3.4 sessions in the 60-74 years old group. No rewards are given to the subjects. They are estimated to have been fully motivated for the recovery. Statistical evaluation was done by paired t-test.
Results: In the first group, the average HR of pretest was 57.3 ± 7.6 bpm and those after BFT of HR speeding was 59.7 ± 4.8 bpm ($P < 0.01$), while in the second group, the pretest HR was 54.3 ± 8.6 bpm and those after BFT of HR speeding was 56.2 ± 9.0 bpm ($P < 0.05$). In both groups the subject were able to increase their HR through BFT with statistical significance.

4.5.2 BFT of HR speeding in the bradycardia of WHO criteria. The subjects were selected with strict criteria (< 50 bpm, WHO criteria) and examined whether these subjects were able to speed their HR with BFT method.
Subjects: 19 subjects of sinus bradycardia without conduction disorders were examined whose HR were less than 50 bpm. The subjects with age of 16-47 are 6 and those with age of 60-74 are 13.
Results: The HR increase was 3.8 ± 4.5 bpm through HR-BFT ($P < 0.05$).
Discussion: Although HR-BFT have been discussed in various kinds of cardiovascular conditions, BFT of bradycardia were few. One US research group reported early in 1980's that self-control of HR speeding was not successful when the subjects were sinus bradycardia. Saito showed that BFT of HR increase was possible through operant technique[1]. With regards to the psychophysiological mechanism of HR modulation, Weiss & Engel[12] examined physiological condition for HR increase using pharmacological method that bradycardic subjects were unsuccessful in speeding HR when the subjects had severe conduction disorders of more than second block. Present study showed if the subjects are free from conduction disorders, they could increase HR regardless of age. Further psychophysiological study of HR and the conduction disorders should be followed.

4.6 Central nervous system and HR-BFT

Plasma catecholamines and HR BFT: The mechanism of various kinds of BFT has been blackbox yet, that is, how central nervous system works, whether neurohormonal network works or not and whether neural reflex in the peripheral system is involved or not, and so on. We examined the relationship between HR-BFT and plasma catecholamines concentration that reflects sympathetic tone level.

4.6.1 Plasma catecholamines and stress loaded HR BFT - within a session.
Subjects: 15 patients with sinus tachycardia practiced HR-BFT with desensitization of stress (DST-HR-BFT)[13].
Procedure: The subjects were taken 1 ml of blood in 3 phases when they were lying 30 min, sitting 30 min. and just after HR BFT. Blood samples were examined with radioenzymatic assay after Johnson and Peuler method[14].
Results: Plasma epinephrine and norepinephrine concentration became higher when patients changed posture from lying to sitting ($P < 0.01$, Table 5). In BFT of HR slowing with desensitization, plasma epinephrine concentration decreased significantly, however, norepinephrine concentration did not change.

4.6.2 Plasma catecholamines and HR BFT in the long range.
Subjects: 40 subjects of functional sinus tachycardia were divided into two groups; The control group is 16 subjects, 7 male and 9 female, with a mean age of 38.6 (18-59 yrs old.) received ordinary HR-BFT. The HR-BFT with desensitization training consists of 24 subjects, 11 male and 13 female, with a mean age of 40.3 (19-57 yrs old).
Procedure: Ordinary HR BFT: This BFT takes 40 min. after 5 min. HR baseline is recorded. Mean number of session was 5.4.
HR-BFT with desensitization training:
During preliminary interview, stressful topics and items, which provoked tachycardia were selected from subjects and Wolpe's Fear Survey Schedule. They were suggested to speak about their concerns, such as diseases or tachycardia provoking factors or to answer questions therapist asked. Mean number of session was 4.8.
Results: Ordinary HR-BFT group: 14 out of 16 subjects decreased their HR between the first and last session (Table 5). HR was 87.5 ± 10.8 bpm in the first session and 79.7 ± 11.5 bpm in the last ($P < 0.05$).
HR-BFT with desensitization training:
22 out of 24 subjects decreased their HR between the first and last session. HR was 84.6 ± 11.5 bpm in the first session and 70.6 ± 7.0 bpm in the last session ($P < 0.01$, Table 5). Plasma epinephrine concentration changed from 75.1 ± 55.9 pg/ml to 55.5 ± 29.1 pg/ml ($P < 0.1$) and norepinephrine, 431.0 ± 311.5 pg/ml to 386.0 ± 215.5 pg/ml respectively, however there was not statistically significant. As plasma catecholamine concentrations reflected sympathetic aspect of autonomic nervous system, this study showed that ,with regards to acute phase of physical reaction, HR-BFT with desensitization method was helpful,

however, in the long range aspect of neurophysiological condition, this mode of BFT was not so potent.

5 DISCUSSION AND SUMMARY

It was suggested that human subjects were able to regulate own HR with an assistance of apparatus in several kinds of cardiovascular dysfunctions, such as sinus tachycardia and sinus bradycardia when the cardiac conduction system was within normal limits. With regards to the mechanism of HR-BFT, subjects seem to use variety of strategies as influences of central nervous function, endocrine system as plasma cathecholamines (especially epinephrine), psychological cues and cognition.

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ヒトの心臓血管系の機能障害における自己コントロールの試み

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概要

ヒトは自分の心拍を器械などの手助けで、認識できれば、いろいろな種類の心臓血管系の機能障害を自分でコントロールできるということが示唆された。それらの障害の中には洞性頻脈、洞性徐脈（刺激伝導系が健全であれば）、各種の不整脈、ある種の高血圧もふくまれる。心臓の自己コントロールのメカニズムとして、被験者や患者は様々な種類の方法を用いていることが見出された。たとえば1）中枢神経機能、2）カテコールアミンとくにアドレナリンの内分泌系、3）心理学的要素や4）認知機能などがあった。

キーワード：バイオフィードバック・トレーニング、自己コントロール、心臓血管系、心拍数、頻脈、徐脈

*保健管理センター
