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Blood pressure biofeedback treatment of white-coat hypertension

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Abstract

Objective: The objective of the study was to compare blood pressure (BP) biofeedback treatment (BF) effects between white-coat hypertension and essential hypertension. **Methods:** Fifteen white-coat hypertensive out-patients and 23 essential hypertensive out-patients were randomly assigned to groups A or B. Subjects in group A underwent BF once a week for a total of four sessions. Those in group B visited the clinic only to measure BP and later underwent the same BF. **Results:** In group A, BPs of white-coat hypertensives and essential hypertensives were significantly reduced by 22/11 and 14/8 mmHg, respectively. In group B, they were unchanged during the same period but later suppressed by BF. Under BF, pulse and respiratory rates were significantly higher, and elevation of diastolic BP due to mental stress testing was better suppressed in white-coat hypertensives than in essential hypertensives. **Conclusion:** This treatment was effective in both types of hypertension, and pressor response to stress seems to be important in the differentiated BF effect.

Keywords: Biofeedback; Blood pressure; Essential hypertension; Mental stress testing; Self-monitoring; White-coat hypertension

Introduction

Approximately 15–60% of borderline hypertension in clinic populations has been reported to be white-coat hypertension, a group of cases that are diagnosed as borderline hypertensive but with normal daytime ambulatory blood pressure (BP) [1,2]. The need for treatment of white-coat hypertension has been discussed based on some evidence showing that white-coat hypertension causes end-organ damage [3–5]. A significant proportion of cardiovascular disease occurs in individuals whose BP is above the optimal level, although not so high as to be diagnosed or treated as essential hypertension [6]. It is recommended that hypertension be prevented and managed to reduce morbidity and mortality by the least intrusive means possible [6]. Therefore, safe and effective interventions are required for white-coat hypertension.

BP biofeedback treatment (BPBF) has been considered since the 1960s as one of the behavioral therapies for lifestyle modification [7,8]. Recently, BPBF using Finapres (Ohmeda Corp., Denver, CO), a noninvasive continuous BP monitoring system [9], has been reported [10]. In our previous study using this device, 20 of the 50 healthy, male students who underwent this BPBF therapy succeeded in reducing their systolic BP (SBP) significantly in one session [11].

However, BPBF has not been evaluated adequately because few studies evaluating this treatment are without methodological problems [12]. Assessing the efficacy of BPBF in hypertension is difficult in that it requires consistent BP measurements [13]. In addition, a number of factors have limited BPBF to clinical practice because of the time and effort it costs both patients and therapists. To resolve these problems, our group developed an easy-to-use BPBF system using an autoshaping method in combination with Finapres and a personal computer. We conducted some pilot studies to examine the clinical usefulness and reliability of this system [11,14,15]. In a randomized control study, patients with essential hypertension underwent 4-week BPBF using this device; their SBP and diastolic BP (DBP) were reduced by approximately 10%, and the

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BP reductions were still significant 3 months after the BPBF [16].

We hypothesized that BPBF would also be effective for white-coat hypertension due to two reasons. One is that all patients in our previous trial [16] met the WHO criteria for essential hypertension, but most of them had lower BP at home compared with that at the clinic, and half of them showed an apparent "white-coat" phenomenon. The second reason is that BPs in white-coat hypertensives and essential hypertensives have been shown to be effected by mental stress [17], and our BPBF significantly suppressed the pressor response of essential hypertensives to this type of stress [16]. To examine our hypothesis, we classified hypertensive patients into a group with white-coat hypertension and into a group with other types of hypertension and applied the same BPBF to a comparable cohort of patients.

Methods

Subjects

Forty-one subjects were selected from out-patients at the Hypertension Clinic of the Branch Hospital of the University of Tokyo according to the following four criteria:

1. DBP measured by the same doctor, independent of the present study, of between 90 and 104 mmHg, which is defined as "mild hypertension" by the Hypertension Detection and Follow-Up Program Cooperative Group and other trials [18,19].
2. Married, and between the age of 30 and 65 years.
3. No history of a β-blocker use. If other antihypertensive medication had been taken, the dosage should have remained unchanged for 3 weeks prior to the period of this study.
4. No damage to target organs such as the heart, brain, retina, or kidney.

Secondary hypertension was ruled out by routine examination, and no restrictions were placed on the duration of hypertension. β-Blocker use was excluded because a possible relationship of β-blockers to stress testing has been reported [20]. Heart damage was assessed by abnormalities of electrocardiogram (ECG) and chest X-ray; for example, left ventricular hypertrophy based on the criteria of Sokolow and Lyon [21], signs of infarction, ischemia, left bundle-branch block, ventricular arrhythmia (class III and IV of the Lown classification) and atrial fibrillation, and cardiac enlargement (cardiothoracic ratio >50%). Brain damage was investigated using computed tomography. Any change in the fundus oculi, based on assessment by an ophthalmologist, was classified according to the criteria of Keith et al. [22]. Proteinuria was defined as ⩾100 mg/dl of protein in urine [23].

The patients were instructed to measure their BP at home in the morning (soon after getting up), in the afternoon (regular time between 2:00 p.m. and 4:00 p.m.), and in the evening (before sleep), for 2 weeks, using an Omron HEM-705CP automated sphygmomanometer (Omron Corp., Tokyo). It was confirmed that the difference between self-measured BP and doctor-measured BP at the clinic was within 5 mmHg. Self-monitoring of BP was completed by the end of the study period. Self-measured BP was comparable for the morning, afternoon, and evening values before the start of the treatment period (analysis of variance, $p > 0.05$). The daily average self-measured BP taken at home was used in this study.

Three patients dropped out within the first 2 weeks because of their jobs. Therefore, 38 patients were studied. Based on the average self-measured BP taken at home, 15 nonmedicated patients with a mean systolic BP (SBP) of <135 mmHg and a mean DBP of <85 mmHg were classified as the white-coat hypertension group [6,24–26]. The remaining 23 patients were classified as the essential hypertension group.

All participating patients were high school or college graduates with basic calculation skills. No patient had been on major or minor tranquilizers or antidepressants before or during the study period. The nature of the procedure used in this study was fully explained beforehand to all participants, and the study was carried out under their informed written consent. The study was conducted from January 1994 to January 1998, and was approved by the ethics committee of the Faculty of Medicine at the University of Tokyo.

Protocol

Selected patients experiencing each type of hypertension were randomly assigned to two groups (group A or group B). After BP self-monitoring at home for 2 weeks, subjects in group A underwent biofeedback treatment once a week for a total of four sessions. Those in group B continued to self-monitor their BP during the sessions as the control period, although they visited the clinic and underwent the same biofeedback treatment after the control period. The protocol of the study is described in Fig. 1. The major characteristics of the patients in group A and group B are shown in Table 1. The degree of neurosis was measured by the Japanese version of the Cornell Medical Index Questionnaire (Fukamachi method), whose reliability in a Japanese population has been examined [27].

Eight patients were prescribed antihypertensive medications, all of whom were essential hypertensives. Three essential hypertensive patients in group A were taking an antihypertensive regimen (one was given 2 mg of benidipine, one was given 30 mg of nifedipine, and one was given 25 mg of captopril), and five essential hypertensive patients were taking an antihypertensive

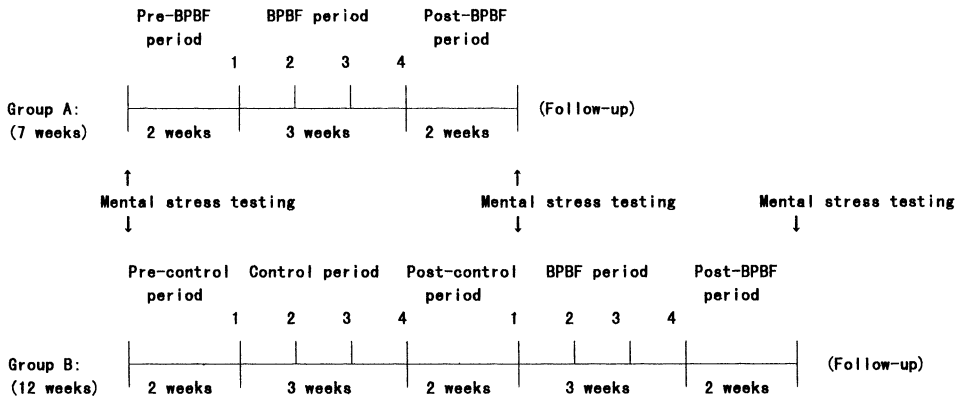

Fig. 1. Protocol of blood pressure biofeedback treatment (BPBF).

regimen (two were given 30 mg of delapril, one was given 180 mg of diltiazem, one was given 30 mg of nifedipine, and one was given 25 mg of alacepril). These patients did not change their dosage during the course of this study.

BPBF system

BP and pulse rate were monitored by Finapres during the BPBF training. Changes in blood volume consequent to each heart beat were sensed by a photoplethysmograph and fed into a special servo-mechanism that adjusted the cuff pressure to equal the pressure of the finger arteries [28]. The data were analyzed by a PC9801 personal computer (NEC Corp., Tokyo, Japan), and displayed visually in real-time as the biofeedback signal for autoshaping [16]. Autoshaping is the gradual modification of a training target done automatically by computer.

When SBP was below target pressure for >70% of a 3-minute trial period, the target SBP was automatically reduced by 5 mmHg in the next trial. If this task was not achieved, then the target SBP remained unchanged in the next trial. A feedback signal (SBP) was displayed as a yellow bar graph that lengthened or shortened horizontally according to BP changes. When BP increased above the target pressure, the color of the zone above it changed to red, and this red zone was what subjects tried to reduce.

BPBF treatment

The doctors in the Hypertension Clinic measured BP by sphygmomanometer before treatment, and all treatments and data measurements were performed by the same therapist in a treatment room at the psychosomatic out-patient clinic.

Subjects underwent BPBF treatment between 2:00 p.m. and 4:00 p.m. once a week. Subjects were asked to sit in a reclining chair during the session in a treatment room kept at 24°C. The Finapres finger cuff was worn on the third finger of the left hand to record BP and pulse rate, and the finger was fixed at the height of the heart by adjustment of the chair arm.

Skin conductance level, skin temperature, electroencephalographic (EEG) α-waves, heart rate variation, and respiratory cycle were recorded using a photic biofeedback apparatus (PFB-1, Pioneer Corp., Tokyo) [29]. Electrodes were connected to the second and third fingers of the right hand for skin conductance level and skin temperature recordings. Electrodes were also connected bilaterally to the forehead to record EEG α-waves, and to the left ear to record the high-frequency component (HF) and the ratio of low-frequency/high-frequency

Table 1
Patient characteristics in white-coat hypertension and essential hypertension[a]

	White-coat hypertension (n = 15)		Essential hypertension (n = 23)	
	Group A (n = 8)	Group B (n = 7)	Group A (n = 11)	Group B (n = 12)
Age (yr)	53 ± 7	54 ± 8	54 ± 11	58 ± 7
Gender (M/F)	2/6	2/5	4/7	3/9
Body mass index (kg/m^2)	21.9 ± 2.3	21.9 ± 1.3	22.8 ± 5.6	21.7 ± 2.3
Duration of illness (yr)	5.6 ± 8.4	2.5 ± 2.3	5.5 ± 10.0	3.7 ± 4.7
Cornell Medical Index[b]	2/6	1/6	2/9	3/9

[a] Values are means ± SD or the number of patients.

[b] Cornell Medical Index (Fukamachi method): questionnaire to assess neurotic levels (areas I to IV) by counting the numbers of physical and psychological symptoms; neurotic patients (area III and IV)/nonneurotic patients (area I and II).

component (LF/HF) of heart rate variance and respiratory cycle. HF and LF/HF have been used as conventional indices of parasympathetic and sympathetic activities, respectively [30].

After the patient had rested for more than 20 minutes, baseline BP was measured by Finapres for 1 minute, and the therapist determined the target SBP. The target BP was approximately equal to the average baseline BP. Each trial consisted of training for 3 minutes and then resting for 1 minute. Each session consisted of five trials. BPBF was given once a week for a total of four sessions. Special psychological methods to strengthen BF effects, such as rewards for each success, were not used in this study, although all subjects reported that they were motivated for the training. The therapist instructed the subjects as follows at the start of each session: "If your BP reaches the target level, try to reduce it by clearing away the red zone any way you can. For example, it may help to watch the display comfortably, keeping your eyes half open, relaxing your shoulders, and breathing deeply."

After the study period, the referring doctors followed the subject's BP, reporting these data to the researcher 1 and then 3 months after the treatment period. No behavioral practice was implemented in the follow-up period.

Mental arithmetic testing

To investigate BP elevation by stress, mental arithmetic testing was performed before and after the treatment period in both groups [31]. Patients were instructed to refrain from food intake for at least 2 hours prior to this testing, and to avoid alcohol, cigarettes, and beverages containing caffeine. After BP at rest had been measured by Finapres during the 1-minute resting period, subjects were asked to perform serial subtractions of the number 17, beginning with the number 1000, during the 3-minute stress period [32]. The difference between the average BP during the resting period and the maximal BP during the stress period was defined as the stress reactivity [17].

Data analysis

Data are expressed as mean ± SD. The paired *t*-test was used to determine the significance of the differences in BP and heart rate between the pre- and posttreatment (or control) periods in each group, and Student's *t*-test was done to compare the two groups (group A vs. B, and white-coat hypertensives vs. essential hypertensives) on the basis of these findings. Then the analysis of variance using the repeat procedure of the Statistical Analysis System (SAS) was done to clarify the effect of session (four sessions) and group (white-coat hypertension group and essential hypertension group) on the physiological parameters during the training. $p < 0.05$ level was considered significant. All analyses were performed using the SAS statistical package [33].

Results

BP changes during BPBF

In the white-coat hypertensives, SBP and DBP at the clinic were significantly decreased by BPBF in group A. Similarly, SBP and DBP elevations induced by mental arithmetic testing in group A were significantly suppressed by BPBF. No parameters in group B changed significantly during the control period (Table 2). The results of BPBF treatment following the control period in group B were as follows: the SBP/DBP results at the clinic, at home, and during the mental arithmetic testing (the degree of elevation) were 152 ± 11/89 ± 4, 125 ± 10/78 ± 9, and +14 ± 19/+10 ± 9 mmHg, respectively. The pre- to posttreatment changes in these three BP parameters in group B were 12 ± 14/8 ± 6, 4 ± 9/2 ± 9, and 11 ± 14/1 ± 12 mmHg, respectively. SBP and DBP at the clinic as well as SBP during the mental arithmetic testing in group B were later significantly decreased by BPBF ($p < 0.05$).

In the essential hypertensives, SBP and DBP at the clinic as well as SBP elevation during the mental arithmetic testing were significantly decreased by BPBF in group A. No parameters in group B changed significantly during the control period (Table 2). After BPBF treatment following the control period in group B, the SBP/DBP results at the clinic, at home, and during the mental arithmetic testing were 152 ± 19/88 ± 11, 143 ± 11/83 ± 5, and +20 ± 9/+14 ± 10 mmHg, respectively. The pre- to posttreatment changes in these three BP parameters in group B were 11 ± 16/7 ± 10, 5 ± 11/5 ± 6, and 3 ± 11/1 ± 9 mmHg, respectively. SBP and DBP at the clinic in group B were later significantly decreased by BPBF ($p < 0.05$).

With regard to the BP differences between the white-coat hypertensives and essential hypertensives, pre- and post-treatment (control) SBP and DBP at home in groups A and B were significantly lower in white-coat hypertensives than in essential hypertensives. The pre- to post-treatment changes in DBP elevation induced by mental arithmetic testing during BPBF in group A were significantly greater in white-coat hypertensives than those in essential hypertensives (Table 2).

Physiological changes due to BPBF during the sessions and trials

Sessions had a main effect on SBP and DBP by showing a gradual decrease throughout the four sessions. Groups had a main effect on pulse rate and respiratory rate. These two parameters in the white-coat hypertension group were significantly higher than those in the

Table 2
Responses of systolic blood pressure (SBP) and diastolic blood pressure (DBP) of white-coat hypertension and essential hypertension to four sessions of biofeedback treatment (BPBF) and to four control sessions (control)[a]

	White-coat hypertension (n = 15)						Essential hypertension (n = 23)					
	BPBF (group A)			Control (group B)			BPBF (group A)			Control (group B)		
	Pre-	Δ	Post-	Pre-	Δ	Post-	Pre-	Δ	Post-	Pre-	Δ	Post-
At clinic												
SBP (mm Hg)	160 ± 9		137 ± 9**	168 ± 20		164 ± 17	152 ± 7		138 ± 17**	166 ± 17		163 ± 11
Decrease in SBP (mm Hg)		22 ± 14			4 ± 15			14 ± 14			3 ± 9	
DBP (mm Hg)	94 ± 4		83 ± 5**	99 ± 5		97 ± 8	94 ± 5		87 ± 9**	94 ± 10		95 ± 10
Decrease in DBP (mm Hg)		11 ± 5			2 ± 5			8 ± 7			−1 ± 8	
At home												
SBP (mm Hg)	125 ± 5‡		121 ± 9‡	127 ± 6‡		129 ± 10‡	143 ± 11		139 ± 11	148 ± 13		148 ± 11
Decrease in SBP (mm Hg)		4 ± 9			−2 ± 9			4 ± 9			0 ± 9	
DBP (mm Hg)	78 ± 6‡		76 ± 8‡	78 ± 5‡		80 ± 10‡	91 ± 4		88 ± 7	88 ± 8		88 ± 5
Decrease in DBP (mm Hg)		2 ± 7			−2 ± 9			3 ± 8			0 ± 10	
Mental arithmetic testing												
SBP (Δ, mm Hg)	30 ± 18		21 ± 10*	28 ± 14		25 ± 14	22 ± 8		13 ± 6*	25 ± 13		23 ± 13
Decrease in ΔSBP (mm Hg)		9 ± 11			3 ± 12			9 ± 10			2 ± 10	
DBP (Δ, mm Hg)	16 ± 9		8 ± 8*	12 ± 19		11 ± 19	16 ± 7		14 ± 8	16 ± 13		15 ± 9
Decrease in ΔDBP (mm Hg)		9 ± 9†			1 ± 7			2 ± 5			1 ± 10	

[a] Values are means ± SD.
* $p < 0.05$ and ** $p < 0.01$, compared with the variable before biofeedback (paired t-test);
† $p < 0.05$ and ‡ $p < 0.01$, compared with the variable of essential hypertension (Student's t-test).

essential hypertension group. No interacting effect was found for physiological parameters (Table 3).

Follow-up study

After the study period, 2 of 15 white-coat hypertensive subjects and 4 of 23 essential hypertensive subjects dropped out of the study, and 2 essential hypertensive subjects had their medications changed up to 3 months after the treatment period. Therefore, 13 white-coat hypertensive subjects and 17 essential hypertensive subjects were left for follow-up.

With regard to the white-coat hypertensives, the average BPs measured by a physician 1 and 3 months after the treatment period were 145 ± 17**/87 ± 7** and 147 ± 12**/90 ± 6** mmHg, respectively. With regard to essential hypertensives, these parameters were 154 ± 9*/89 ± 11** and 147 ± 8**/90 ± 6* mmHg, respectively (*$p < 0.05$ and **$p < 0.01$, compared with the pretreatment period). BP at the clinic remained significant 3 months after treatment in both white-coat hypertensives and essential hypertensives. No significant difference in BP at the clinic was found between white-coat hypertensives and essential hypertensives.

Discussion

A primary finding in the present study was that patients with white-coat hypertension manifested significant BP reductions due to BPBF. BP in the clinic and BP elevation induced by mental stress testing decreased significantly after the four sessions of BPBF, although they remained unchanged during the control sessions. BP decrease in the clinic was still significant 3 months after the BPBF. No significant changes were found for self-measured BP. The BPs during the BPBF training were measured continuously using the Finapres blood monitor, which has level of reliability that has been fully confirmed [9]. In addition, the BPBF protocol used in the present study was previously confirmed to be effective in essential hypertension [16], and was performed by a trained physician blinded to the patients' status to minimize measurement bias. The findings were consistent with our previous study on essential hypertension [16], and therefore strongly suggest that BPBF is also effective in white-coat hypertension.

Compared with essential hypertension, DBP response to mental stress testing was more greatly suppressed by BPBF, and pulse rate and respiration rate were significantly higher during the BPBF trials in white-coat hypertension. The findings regarding pulse rate and DBP response to stress seem to be suggestive, because some studies have indicated that the perception and discrimination of arterial pulsation is important for the development and control of physiological functions such as BP, and the heart beat perception accuracy is increased when BPBF is provided [34,35]. The pressor response to stress including pulsation might play an important role in the differentiated BPBF effects.

However, other studies failed to find any significant differences in response of white-coat hypertensives to mental arithmetic as compared with essential hypertensives, despite the presence of a relatively large response in the former [36,37]. One possible reason for this disagreement may have to do with the effect of confounders of white-coat hypertension. The major contributing factors of white-coat hypertension are gender, age, and duration of hypertension [1], and these factors may have to be controlled for when the results are analyzed and interpreted. Another possible reason is the cultural differences in BP responses to mental arithmetic testing. Our previous trial in a group of middle-aged, Japanese women showed significant hyperresponse to mental stress testing in white-coat hypertension [17]. Further studies need to be done to clarify the detailed mechanisms of the differentiated BPBF response and to determine whether BPBF is more effective for white-coat hypertension.

SBP and DBP significantly decreased in both white-coat hypertension and essential hypertension throughout all the sessions, but other physical parameters, such as pulse rate and skin temperature, remained unchanged in this study. These findings are inconsistent with a generalized relaxation response, which is characterized by decreased metabolism, lower BP, and slower rate of breathing and heart rate, in association with feelings of calmness and control [38,39]. Although the generation of the integrated relaxation response is considered to be a key component to reduce in BP through behavioral medicine interventions [40], it is possible that the subjects might learn to control BP as a specific physical parameter during our BPBF. A qualitative review of studies on stress management techniques supports the hypothesis of heterogeneous effects of biofeedback; that is, electromyographic biofeedback has greater muscle effects than progressive relaxation, and thermal biofeedback has greater temperature effects than autogenic training [41]. Some researchers have commented that subjects cannot learn to control BP successfully if they "try too hard" [42]. Rather, successful subjects seem to adopt a passive attitude, letting things happen rather than making them happen. They might learn autonomic control with an appropriate cognitive state specific to the lowering of BP.

Regarding the mechanism of extended BPBF effect, there is still no confirmed theory [43–45]. Recently, it was found that BPBF was as effective as placebo biofeedback in lowering BP, leading researchers to suggest that the capability of individuals to lower blood pressure was independent of the feedback signal [46]. The short-term results in the present study could be due to this nonspecific placebo effect. However, the long-term BPBF effects observed at 1- and 3-month follow-up

Table 3
Changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), pulse rate (PR), respiratory cycle (RC), skin conductance level (SCL), skin surface temperature (SST), α-wave cycle (α-WC) and α-wave amplitude (α-WA) of electroencepalography, and low frequency (LF) and the ratio of low frequency to high frequency (LF/HF) of heart variations during four sessions (SES) of biofeedback treatment of mild hypertension (analysis of variances)[a]

	White-coat hypertension (n = 15)				Essential hypertension (n = 23)				Significance		
	First SES	Second SES	Third SES	Fourth SES	First SES	Second SES	Third SES	Fourth SES	Type	Session	Type × session
SBP[b] (mm Hg)	158 ± 13	143 ± 21	133 ± 18	141 ± 18	163 ± 21	149 ± 12	151 ± 15	135 ± 15	NS[c] ($F = 2.62$, $df = 1$)	$p < 0.01$ ($F = 12.44$, $df = 3$)	NS ($F = 2.53$, $df = 3$)
DBP[b] (mm Hg)	89 ± 11	88 ± 9	81 ± 7	82 ± 8	86 ± 11	93 ± 13	92 ± 14	80 ± 8	NS ($F = 1.52$, $df = 1$)	$p < 0.01$ ($F = 6.05$, $df = 3$)	$p < 0.01$ ($F = 2.22$, $df = 3$)
PR[b] (beats/min)	80 ± 15	81 ± 7	83 ± 11	79 ± 11	69 ± 11	73 ± 10	72 ± 10	70 ± 7	$p < 0.01$ ($F = 24.99$, $df = 1$)	NS ($F = 0.87$, $df = 3$)	NS ($F = 0.16$, $df = 3$)
RC (cycles/min)	20 ± 4	19 ± 3	18 ± 3	18 ± 5	16 ± 2	17 ± 4	18 ± 4	18 ± 3	$p < 0.05$ ($F = 4.78$, $df = 1$)	NS ($F = 0.09$, $df = 3$)	NS ($F = 1.44$, $df = 3$)
SCL (μS)	1.8 ± 1.3	1.7 ± 1.0	1.1 ± 0.3	1.6 ± 1.2	1.4 ± 0.7	1.4 ± 0.6	1.6 ± 0.5	1.5 ± 0.7	NS ($F = 0.35$, $df = 1$)	NS ($F = 0.30$, $df = 3$)	NS ($F = 2.25$, $df = 3$)
SST (°C)	34.0 ± 1.0	33.8 ± 1.0	33.9 ± 1.2	33.9 ± 1.2	33.9 ± 1.0	34.1 ± 0.7	33.9 ± 0.7	34.0 ± 0.8	NS ($F = 0.41$, $df = 1$)	NS ($F = 0.03$, $df = 3$)	NS ($F = 0.20$, $df = 3$)
α-WC (Hz)	9.1 ± 0.2	9.3 ± 0.3	9.1 ± 0.1	9.4 ± 0.3	9.3 ± 0.3	9.4 ± 0.2	9.3 ± 0.3	8.9 ± 2.0	NS ($F = 0.03$, $df = 1$)	NS ($F = 0.76$, $df = 3$)	NS ($F = 1.59$, $df = 3$)
α-WA (relative degree)	31.5 ± 4.9	29.3 ± 4.8	28.2 ± 4.4	30.0 ± 6.4	30.5 ± 4.4	30.4 ± 4.2	31.8 ± 6.7	28.8 ± 2.3	NS ($F = 0.60$, $df = 1$)	NS ($F = 0.80$, $df = 3$)	NS ($F = 2.00$, $df = 3$)
HF ($msec^2$)	5.4 ± 2.3	4.5 ± 4.3	7.0 ± 3.7	6.6 ± 4.2	4.5 ± 5.5	4.4 ± 3.1	4.8 ± 5.2	5.3 ± 2.6	NS ($F = 2.37$, $df = 1$)	NS ($F = 0.50$, $df = 3$)	NS ($F = 0.24$, $df = 3$)
LF/HF (relative degree)	1.3 ± 1.8	1.4 ± 1.3	0.5 ± 0.3	0.6 ± 0.5	1.1 ± 0.9	1.0 ± 0.8	0.7 ± 0.4	1.0 ± 0.9	NS ($F = 0.04$, $df = 1$)	NS ($F = 1.78$, $df = 3$)	NS ($F = 1.10$, $df = 3$)

[a] Values are means ± SD.
[b] Measured by Finapres.
[c] NS means $p > 0.05$.

assessments are not easily explained by the placebo effect. The subjects continued to self-monitor BP for 7 or 12 weeks, and this procedure could potentially make them aware of the importance of self-control of BP. Another possible explanation is that, once the appropriate cognitive state is identified, the task of BP control might become simply to maintain it for a long period [42]. Subjects might also be highly motivated by the improvement in BP and encouraged to change to a healthier lifestyle to maintain their BP level.

A comprehensive investigation of BPBF, including the patient–doctor relationship, adaptation, expectancy, habituation, and suggestibility, should be made in order to define its framework [13]. In the present study, a trained physician specializing in psychosomatic medicine, who was blinded to the subjects until the completion of the BPBF, performed all BPBF procedures in order to control these potential confounders as much as possible. The subjects were seen in the BPBF room and the details of the procedures were explained before the BPBF to reduce their anxieties concerning treatment and strengthen their motivation. In order to standardize the treatment, a specific relaxation method was not used and subjects were instructed to watch the monitor comfortably. In spite of these efforts, degrees of adaptation, expectancy, anxiety, and tension may have differed among subjects, although the correlation of these psychological parameters to treatment effect could not be assessed in the present study. Using a standardized questionnaire would be one possible way to control for the effects of psychological status.

In summary, BPBF suppressed SBP, DBP, and the pressor response to stress in white-coat hypertension in a sample from a middle-aged, Japanese population, with the degree of suppression of the pressor response greater than in patients with essential hypertension. BPBF may be useful not only as a nonpharmacological treatment for essential hypertension but also as an intervention to prevent the development of true hypertension and, as a result, reduce the cardiac risk in patients with white-coat hypertension.

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