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Relationship between body composition changes and the blood pressure response to exercise test in overweight Japanese subjects.

Nobuyuki Miyatake*   Sumiko Matsumoto†

Hidetaka Nishikawa‡   Takeyuki Numata**

*Okayama Southern Institute of Health,

†Okayama Southern Institute of Health,

‡Okayama Southern Institute of Health,

**Okayama Southern Institute of Health,

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Abstract

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KEYWORDS: body composition, exercise test, blood pressure response, overweight

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Original Article

Relationship between Body Composition Changes and the Blood Pressure Response to Exercise Test in Overweight Japanese Subjects

Nobuyuki Miyatake*, Sumiko Matsumoto, Hidetaka Nishikawa, and Takeyuki Numata

Okayama Southern Institute of Health, Okayama 700–0952, Japan

We investigated the link between changes in body composition and the blood pressure (BP) response to exercise in overweight Japanese by a retrospective clinical study carried out over a 3-year period. We analyzed data for 38 overweight Japanese aged 22–69 years (47.8 ± 11.4) at baseline. Among the participants, 32 overweight subjects (body mass index: BMI, 29.0 ± 3.0 kg/m^2) were further analyzed with a 3-year follow up. BP at rest, the BP response to an exercise test, the aerobic exercise-level determined ventilatory threshold (VT), and body composition were evaluated at an interval of 1 year. During the study period, there were 6 drop outs, who started to receive anti-hypertensive drugs because of the development of hypertension. Based on analysis of follow up data, parameters of body composition were significantly reduced over the 3 years. Systolic BP (SBP) at rest and at VT was also reduced. In addition, delta SBP (△: delta represents positive change in parameters) at VT was positively correlated with △parameters of body composition over the 3 years. In overweight subjects with increased body weight, there was a significant time (pre vs year 3) effect and interactions by 2 factor-factorial ANOVA. The present study indicates that changes in body composition are closely linked to the SBP response to an exercise test.

Key words: body composition, exercise test, blood pressure response, overweight

Severely obese subjects have been shown to have a high mortality rate [1] and to be severely affected by diseases such as coronary heart disease, diabetes mellitus, dyslipidemia, and hypertension [2]. The modern lifestyle of high-calorie diets and reduced exercise parallels the increased prevalence of obese subjects. For the management of obesity, exact assessments of obesity and the development of effective treatments are urgently required.

In this respect, reducing body weight and improving body composition are important for obese subjects to prevent obesity-related disease. However, the effects of changes in body composition on the blood pressure (BP) response to an exercise test remain to be investigated. In this study, we investigated the body composition, BP at rest, and BP response to an exercise test in overweight subjects over a 3-year period. In addition, the effects of changes in body composition on BP at rest and the BP response to an exercise test were also investigated.

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*Corresponding author. Phone:+81–86–246–6250; Fax:+81–86–246–6330
E-mail:center@okakenko.jp (N. Miyatake)

Subjects and Methods

Subjects. We used data for 38 Japanese overweight subjects aged 22–69 years (47.8 ± 11.4) retrospectively from a database of 6,764 subjects who provided written informed consent and who met the following criteria: (1) received an annual health check-up at baseline from June 1997 to March 2000, (2) being overweight at baseline, (3) received an annual health check-up every year with a follow-up duration of 3 years, and (4) no electrocardiogram changes in response to an exercise test (Table 1). Overweight was diagnosed according to the criteria of WHO [3], and the average body mass index (BMI) of overweight subjects was 29.1 ± 3.2 kg/m^2 (25.0–37.0). No subjects received any medications for diabetes, hypertension, and/or dyslipidemia at baseline.

At an annual health check-up, all subjects were instructed to change their lifestyle according to the results by well-trained medical staff.

BP measurements at rest. The resting systolic BP (SBP) and diastolic BP (DBP) were measured indirectly using a mercury sphygmomanometer placed on the right arm of the seated participant after at least 15 min of rest.

Anthropometric and body composition measurements. The anthropometric and body compositions were evaluated based on the following parameters: height, body weight, BMI, waist circumference, hip circumference, waist-hip ratio and body-fat percentage. BMI was calculated by weight / (height)^2 (kg/m^2). The waist circumference was measured at the umbilical level, and the hip was measured at the widest circumferences over the trochanter in standing subjects after normal expiration. Body-fat percentage was measured by an air displacement plethysmograph called the BOD POD Body Composition System (Life Measurement Instruments, Concord, CA, USA) [4, 5].

Aerobic exercise level. A graded ergometer exercise protocol [6] was carried out. After breakfast (2 h), a resting ECG was recorded and blood pressure was measured. All subjects were then given a graded exercise after 3 min of pedaling on an unloaded bicycle ergometer (Excalibur V2.0, Lode BV, Groningen, Netherlands). The profile of incremental workloads was automatically defined by the methods of Jones [6], in which the workloads reach the predicted $\dot{V}O_2$max in 10-min. A pedaling cycle of 60 rpm was maintained. Loading was terminated when the appearance of symptoms forced the subject to stop. During the test, ECG was monitored continuously together with the recording of heart rate. Their BP were continuously measured every minute using an auscultator with a pressure cuff around the right upper arm connected to a mercury sphygmomanometer. Expired gas was collected, and rates of oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were measured breath-by-breath using the cardiopulmonary gas exchange system (Oxycon Alpha, Mijnhrdt b.v., Netherlands). The ventilatory threshold (VT) was determined by the standard of Wasserman *et al.* [7], Davis *et al.* [8] and the V-slope method of Beaver [9] from $\dot{V}O_2$, $\dot{V}CO_2$, and minute ventilation ($\dot{V}E$). At VT, BP, $\dot{V}O_2$ (ml/kg/min), work rate (W), and heart rate (beats/min) were measured and recorded. During exercise testing, subjects were asked to report the degree of exertion every minute, based on the Borg scale [10], *i.e.* the rate of perceived exertion (RPE).

Statistical Analysis. All data are expressed as mean ± standard deviation (SD) values. Statistical analysis was performed by one-factor factorial ANOVA, Scheffe's F test, 2-factor factorial

Table 1 Clinical Profiles of 38 overweight subjects

Number of subjects	38
Men/Women	22/16
Age	47.8 ± 11.4
Body weight (kg)	76.2 ± 9.3
BMI (kg/m^2)	29.1 ± 3.2
Body fat percentage (%)	33.6 ± 6.9
Waist circumference (cm)	91.9 ± 6.4
Hip circumference (cm)	99.3 ± 5.5
Waist hip ratio	0.93 ± 0.06
SBP at rest (mmHg)	140.8 ± 20.3
DBP at rest (mmHg)	86.4 ± 17.5
Oxygen uptake at VT (ml/kg/min)	12.8 ± 2.2
Heart rate at VT (beat/min)	101.0 ± 11.2
Work rate at VT (W)	67.2 ± 19.7
RPE at VT	11.4 ± 1.8
SBP at VT (mmHg)	163.8 ± 26.1
DBP at VT (mmHg)	91.4 ± 19.8

Mean ± SD
BMI, body mass index; DBP, diastolic blood pressure; RPE, rate of perceived exertion; SBP, systolic blood pressure; VT, ventilatory threshold.

ANOVA, and unpaired t test: $p < 0.05$ was considered to be statistically significant. The Pearson's correlation coefficients were calculated as well as tested for the significance of the linear relationship among continuous variables.

Results

We evaluated the relationship between body composition and BP using the baseline data (Table 2). A weak relationship was observed between body-fat percentage and SBP at rest ($r = -0.372$). However, no significant relationship was noted between other parameters of body composition and BP.

Over the 3-year period, 6 overweight subjects started anti-hypertensive drugs because of hypertension. We compared follow-up subjects ($n = 32$) with drop-out subjects ($n = 6$) at baseline (Table 3). In drop-out subjects, SBP and DBP at rest were significantly higher than those in follow-up subjects. SBP and DBP at VT were also significantly higher in drop-out subjects than in follow-up subjects. There was no significant difference in other parameters such as body composition and aerobic exercise level.

Changes in the parameters of follow up subjects

Table 2 Simple Correlation analysis between BP and body composition at baseline

	SBP at rest		DBP at rest		SBP at VT		DBP at VT	
	r	*p*	r	*p*	r	*p*	r	*p*
Body weight (kg)	0.159	0.3418	0.063	0.7074	0.057	0.7356	0.198	0.2331
BMI (kg/m^2)	− 0.100	0.5513	− 0.202	0.2241	0.149	0.3735	0.125	0.4542
Body fat percentage (%)	− 0.372	0.0213	− 0.181	0.2768	0.003	0.9838	− 0.278	0.0906
Waist circumference (cm)	0.315	0.0538	0.105	0.5295	0.208	0.2100	0.137	0.4125
Hip circumference (cm)	0.166	0.3182	− 0.144	0.3881	− 0.111	0.5074	0.158	0.3432

BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Table 3 Comparison of clinical profiles between follow up and drop out groups

	Follow up group	Drop out group	*p*
Number of subjects	32	6	
Age	47.0 ± 11.7	52.2 ± 9.4	0.3157
Body weight (kg)	76.2 ± 9.6	76.4 ± 8.4	0.9770
BMI (kg/m^2)	29.0 ± 3.0	29.7 ± 4.7	0.6387
Body fat percentage (%)	33.8 ± 7.3	32.4 ± 4.4	0.6517
Waist circumference (cm)	91.6 ± 6.8	94.2 ± 2.1	0.3645
Hip circumference (cm)	99.5 ± 5.5	98.5 ± 5.8	0.6781
Waist hip ratio	0.92 ± 0.06	0.96 ± 0.05	0.1847
SBP at rest (mmHg)	136.5 ± 17.8	163.7 ± 18.1	0.0016
DBP at rest (mmHg)	83.0 ± 16.3	104.5 ± 12.6	0.0042
Oxygen uptake at VT (ml/kg/min)	12.6 ± 2.1	14.0 ± 2.8	0.1881
Heart rate at VT (beat/min)	101.1 ± 11.5	100.3 ± 10.5	0.8763
Work rate at VT (W)	67.5 ± 19.8	65.8 ± 21.1	0.8553
RPE at VT	11.4 ± 1.9	11.3 ± 1.5	0.9593
SBP at VT (mmHg)	158.9 ± 22.6	195.5 ± 17.9	0.0007
DBP at VT (mmHg)	88.7 ± 20.2	107.0 ± 10.3	0.0384

Mean ± SD
BMI, body mass index; DBP, diastolic blood pressure; RPE, rate of perceived exertion; SBP, systolic blood pressure; VT, ventilatory threshold.

(n = 32) over the 3 years are summarized in Table 4. By one-factor factorial ANOVA and Scheffe's F test, body weight and hip circumference were significantly reduced at year 2. BMI and the waist-hip ratio were also reduced at year 2 and maintained until year 3. Waist circumference was significantly reduced at year 1, and was maintained until year 3. Body-fat percentage was significantly reduced at year 2 compared with pre and year 1, and was maintained until year 3. SBP at rest was significantly lowered at year 1 and maintained until year 3. SBP at VT was also lowered at year 2 and maintained until year 3. Heart rate at VT was significantly reduced at year 2.

We investigated the correlation between △BP (△ represents a positive change in parameters) and △body composition over the 3 years. In men, △SBP at VT was significantly correlated with △body weight, △BMI, and △Hip circumference. △DBP at VT was also significantly correlated with △body-fat percentage and △hip circumference. In women, △SBP at VT was significantly correlated with △body weight and △BMI. In a total of 32 overweight subjects, △SBP at VT was significantly correlated with △body weight (r = 0.539), △BMI (r = 0.556), △body-fat percentage (r = 0.464), and △waist circumference (r = 0.498) (Table 5). However, △SBP at rest, △DBP at rest, and △DBP at VT did not correlate with △body composition.

Finally, we classified the subjects into 2 groups according to changes in body weight over the 3 years (increased body weight group: n = 12, reduced body weight group: n = 20) (Table 6). By 2 factor-factorial ANOVA, there was significant time (pre and 3 year) effect and interactions in SBP at VT. There was only a time effect in SBP at rest and only a group effect in DBP at rest and at VT.

Discussion

The main finding of this study is the link between changes in body composition and changes in BP during a 3-year follow-up period. The alterations in body composition in overweight Japanese subjects were closely related to an exaggerated BP response to exercise. Several prospective epidemiologic studies in normotensive subjects have demonstrated that an exaggerated BP response to a given and relative exercise intensity [11-14] and a lower quintile of the $\dot{V}O_2$ max or endurance capacity [15] are good predictors for developing hypertension. Tsumura K *et al.* [12] have reported, based on a prospective cohort study of a total of 6,557 Japanese, that the

Table 4 Changes in clinical profiles during 3 Years in 32 overweight subjects

	Pre	Year 1	Year 2	Year 3
Number of subjects	32 (18 Men and 14 Women)			
Body Weight (kg)	76.2 ± 9.6	74.9 ± 9.4	74.0 ± 9.1[a]	74.8 ± 10.4
BMI (kg/m²)	29.0 ± 3.0	28.4 ± 2.9	28.0 ± 3.0[a]	28.4 ± 3.6[a]
Body fat percentage (%)	33.8 ± 7.3	33.9 ± 7.8	32.3 ± 7.0[ab]	32.3 ± 8.0[ab]
Waist circumference (cm)	91.6 ± 6.8	89.9 ± 7.3[a]	88.4 ± 8.2[a]	89.1 ± 9.0[a]
Hip circumference (cm)	99.5 ± 5.5	99.0 ± 5.3	98.1 ± 4.8[a]	98.5 ± 5.6
Waist hip ratio	0.92 ± 0.06	0.91 ± 0.07	0.90 ± 0.08[a]	0.91 ± 0.08[a]
SBP at rest (mmHg)	136.5 ± 17.8	129.1 ± 15.2[a]	130.9 ± 16.6[a]	131.3 ± 16.5[a]
DBP at rest (mmHg)	83.0 ± 16.3	82.4 ± 14.1	81.7 ± 11.3	84.9 ± 11.0
Oxygen uptake at VT (ml/kg/min)	12.6 ± 2.1	13.0 ± 2.4	13.1 ± 2.6	13.1 ± 1.9
Heart rate at VT (beat/min)	101.1 ± 11.5	99.1 ± 9.7	96.9 ± 10.7[a]	98.8 ± 11.2
Work rate at VT (W)	67.5 ± 19.8	71.7 ± 21.1	70.9 ± 24.9	70.5 ± 23.4
RPE at VT	11.4 ± 1.9	11.9 ± 1.2	11.3 ± 1.2	11.3 ± 1.4
SBP at VT (mmHg)	158.9 ± 22.6	152.9 ± 22.5	145.4 ± 22.9[ab]	150.6 ± 24.1[a]
DBP at VT (mmHg)	88.7 ± 20.2	87.1 ± 15.0	84.1 ± 16.9	86.9 ± 15.9

Mean ± SD

a: $p < 0.05$ vs pre; b: $p < 0.05$ vs Year 1.

BMI, body mass index; DBP, diastolic blood pressure; RPE, rate of perceived exertion; SBP, systolic blood pressure; VT, ventilatory threshold.

BP response after exercise with a Master's two-step is associated with an increased risk of hypertension, independent of resting BP. Matthews CE *et al.* [13] have also reported that an exaggerated BP response to exercise is independently associated with an increased risk of future hypertension by longitudinal analysis of 5,386 healthy normotensive men. The mechanisms by which the BP response to exercise predict the development of hypertension have not been clarified. The structure of the systemic resistance vessels or sympathetic adaptation may have been changed before the appearance of hypertension [16–19]. In this study, we could not explore whether an exaggerated BP response to exercise is closely linked to future hypertension in overweight Japanese. However, these findings lead to the idea

Table 5 Simple correlation analysis between delta (△) BP and delta (△) body composition during 3 years

	△SBP at rest		△DBP at rest		△SBP at VT		△DBP at VT	
	r	*P*	r	*P*	r	*P*	r	*P*
Total								
△Body weight (kg)	−0.117	0.5235	0.038	0.8353	0.539	0.0018	0.054	0.7718
△BMI (kg/m^2)	0.141	0.4429	0.028	0.8787	0.556	0.0012	0.051	0.7858
△Body fat percentage (%)	−0.124	0.4980	0.068	0.7113	0.464	0.0085	0.144	0.4402
△Waist circumference (cm)	−0.060	0.7441	0.081	0.6603	0.498	0.0044	0.028	0.8824
△Hip circumference (cm)	0.054	0.7698	−0.050	0.7886	0.285	0.1198	0.210	0.2577
Men								
△Body weight (kg)	0.057	0.8225	0.003	0.9912	0.509	0.0308	0.350	0.1540
△BMI (kg/m^2)	0.041	0.8709	−0.071	0.7785	0.510	0.0305	0.416	0.0863
△Body fat percentage (%)	0.056	0.8224	0.021	0.9345	0.392	0.1075	0.486	0.0409
△Waist circumference (cm)	−0.101	0.0509	−0.048	0.8485	0.453	0.0587	0.319	0.1969
△Hip circumference (cm)	−0.099	0.6946	−0.089	0.7242	0.477	0.0453	0.718	0.0008
Women								
△Body weight (kg)	−0.333	0.2453	0.109	0.7106	0.564	0.0445	0.117	0.6592
△BMI (kg/m^2)	−0.292	0.3111	0.178	0.5418	0.579	0.0381	−0.112	0.7165
△Body fat percentage (%)	−0.350	0.2195	0.162	0.5806	0.520	0.0683	−0.075	0.8075
△Waist circumference (cm)	0.016	0.9572	0.403	0.1528	0.549	0.0519	−0.145	0.6368
△Hip circumference (cm)	−0.042	0.8869	0.052	0.8595	0.169	0.5810	−0.053	0.8624

BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Table 6 Comparison of BP between increased and decreased body weight groups

	Pre	Year 1	Year 2	Year 3	
SBP at VT					group: $p=0.1479$
Increased body weight group	158.6 ± 20.2	158.2 ± 15.8	153.9 ± 17.6	165.6 ± 19.3	time: $p=0.0055$
Reduced body weight group	159.1 ± 24.3	150.0 ± 25.3	140.7 ± 24.4	142.4 ± 22.8	interaction: $p=0.0034$
DBP at VT					group: $p=0.0234$
Increased body weight group	96.2 ± 23.9	92.5 ± 15.7	93.8 ± 16.1	95.4 ± 18.5	time: $p=0.5571$
Reduced body weight group	84.6 ± 17.0	84.2 ± 14.2	78.8 ± 15.2	82.2 ± 12.5	interaction: $p=0.6935$
SBP at rest					group: $p=0.1539$
Increased body weight group	143.2 ± 11.1	133.3 ± 12.3	137.5 ± 14.2	134.4 ± 19.2	time: $p=0.0089$
Reduced body weight group	133.0 ± 19.8	126.9 ± 16.4	127.5 ± 17.1	129.7 ± 15.2	interaction: $p=0.5874$
DBP at rest					group: $p=0.0342$
Increased body weight group	91.1 ± 12.7	85.7 ± 13.2	85.6 ± 9.9	91.7 ± 9.0	time: $p=0.3358$
Reduced body weight group	78.7 ± 16.6	80.7 ± 14.5	79.6 ± 11.6	81.3 ± 10.4	interaction: $p=0.3456$

DBP, diastolic blood pressure; SBP, systolic blood pressure.

that such high-risk subjects should frequently be counseled and that nonpharmacological strategies should be investigated with regard to their ability to prevent hypertension.

According to the relationship between body weight and BP at rest, a review by Hagberg *et al.* [20] reported a correlation of 0.11, which is not significant, between the reduction in SBP and the reduction in body mass in 61 studies reporting body weight changes in hypertensives with exercise training. The authors concluded that the exercise training-induced reductions in SBP and DBP are not the result of weight changes with exercise. In this study, as in previous studies, only the body-fat percentage was found to be weakly correlated with SBP at rest, and no significant correlations were noted between body composition parameters and BP. However, changes in body composition such as body weight, BMI, body-fat percentage, and waist circumference were significantly correlated with changes in SBP at VT. In addition, by 2 factor-factorial ANOVA, there was a significant time (pre and 3 year) effect and interactions in SBP at VT. Based on the relationship between obesity and hypertension, Oshida Y *et al.* have reported that insulin is an important factor in BP elevation in older obese subjects [21]. Kanai *et al.* have reported that, through a combination of low-calorie diet and exercise therapy, improvements of glucose intolerance can occur, which may then be involved in BP changes in obese hypertensive women [22]. The improvement of leptin resistance [23] or a reduction of the renin-angiotensin-aldosterone system in plasma and adipose tissue [24] may contribute to a reduced BP. However, we failed to define the mechanisms linking change in body composition and the SBP response to an exercise test. The small sample size in our study as well as sex differences makes it difficult to infer causality between body composition and the BP response to exercise. Therefore, our findings are applicable to clinical and public health practice settings. In conclusion, our findings indicate that the improvement of body composition may be one of the major determinant factors for preventing future hypertension in overweight Japanese. In addition, an exaggerated BP response to exercise test is a useful predictor of future hypertension in overweight Japanese.

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