Changes in body mass index, waist circumference and percent body fat rather than their baseline values were significantly associated with incident hypertension after being adjusted for baseline blood pressure in men

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ABSTRACT

Objectives To compare the effects of baseline anthropometric parameters and their changes on incident hypertension.

Design A retrospective 5-year follow-up study.

Setting Annual general health screenings at a medical check-up center.

Participants A general health screening population including 1,221 men and 815 women who were not with hypertension at baseline.

Main outcome measures Hazard ratios (HRs) of incident hypertension for baseline body mass index (BMI), waist circumference (WC) and percent body fat (PBF) as well as changes in them after being adjusted for baseline blood pressure.

Results The cumulative incidence of hypertension was 23.7% in men and 13.5% in women. The baseline BMI, WC and PBF were not significantly associated with incident hypertension adjusted for baseline blood pressure and other confounders, while the changes in BMI, WC and PBF during follow-up were significantly associated with incident hypertension in men. All the associations with incident hypertension were not significant except for those of each 1 kg/m² change in BMI during follow-up and for the highest quartile of baseline BMI and PBF compared with the lowest quartile in women. Baseline BMI, WC and PBF were not significantly correlated with changes in blood pressure except for inverse correlations of BMI and PBF with blood pressure changes in men while changes in BMI, WC and PBF were significantly positively correlated with changes in blood pressure.

Conclusions Changes in BMI, WC and PBF during follow-up rather than their baseline values were significantly associated with incident hypertension after being adjusted for baseline blood pressure in men. (HEP. 2017; 44: 567-574.)

Key words obesity, BMI, waist circumference, percent body fat, incident hypertension

Introduction

Hypertension is one of the most prevalent risk factors of cardiovascular diseases. The first line of treatment for hypertension is dietary changes including a reduction of salt and calorie intake, doing more physical exercise, and obtaining weight loss. Cross-sectional and longitudinal epidemiological studies have shown that blood pressure and hypertension are increased significantly with greater body mass index (BMI) and waist circumference (WC) in normal-weight, overweight and obese men and women, and baseline overweight as well as obesity are reported to be an important risk factor for hypertension1-12). Several longitudinal studies relate hypertension to changes in BMI or adiposity over time13-22). Given the association between long-term weight gain and hypertension risk, cohort studies on the association between baseline obesity and incident hypertension1-12) have a statistical problem because fixed baseline BMI cannot account for any change in BMI during the observation period13-22). Obese individuals with metabolic risk factors may make an effort to reduce their body weight because obesity is well known to be unhealthy, as is the concept of metabolic syndrome25, 26). Few studies demonstrated that a higher baseline BMI is still associated with a higher risk of hypertension, even if the baseline BMI remained stable during the follow-up period27, 28). A study reported that the odds for hypertension were significantly related to BMI at follow-up when adjusted for baseline BMI, but generally not to baseline BMI when adjusted for follow-up BMI29). Another very long time follow-up study reported that men of normal weight at age 25 years who became overweight or obese at age 45 years were at increased risk compared with men who were overweight or obese at age 25 years who returned to normal weight at age 45 years30).

The aims of the present 5-year follow-up study are to investigate the associations between baseline BMI, WC and percent body fat (PBI) as well as changes in them during follow-up and incident hypertension in a health screening population.

Subjects and Methods

This study was approved by the ethics committee of Tachikawa Medical Center and the procedures were in accordance with the Declaration of Helsinki, 1964 and Declaration of Tokyo, 1975, as
following equation according to a recommendation from the mated glomerular filtration rate (eGFR) was calculated using the-
measurement limit was considered to be 0.01 mg/L. Esti-
tment of hs-CRP, which was performed at BML General Labora-
tory (Tokyo, Japan) with nephelometry using N-latex CRP-2
med at BML Nagaoka (Nagaoka, Japan) except for the assess-
chemical assessments were all per-
measured using a direct surfactant method with Choletest-LDL
was qualitatively measured with a dipstick. LDL cholesterol was
ing for 30 minutes or longer two times or more per week. The
- exercise, antidiabetic and antihyperlipidemic drugs. Physical activity
- about their history of coronary heart disease and stroke, smoking,
- required to complete a questionnaire including questions
- of BMI, WC and PBF and changes in them during follow-up as well
- was defined as an SBP ≥140 mmHg and/or a diastolic
- noted between potential candidates and
- subjects who had a history of coronary heart disease or stroke or used
- among them, 1,221 men aged 24–81 years and 815 women aged
- revisited our Medical Check-up Center for annual health screenings
- and March 2014 and were actually enrolled in the follow-up study. Hypertension was defined as
- as a systolic blood pressure (SBP) ≥140 mmHg and/or a diastolic
- blood pressure (DBP) ≥90 mmHg and/or the use of antihypertensive drugs. Prehypertension was defined as
- (Siemens Healthcare Japan, Tokyo, Japan). The measurement
- uric acid, high-sensitivity C-reactive protein (hs-CRP), hemoglobin A1c (HbA1c) and creatinine. Proteinuria was
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- were obtained to measure
- fasting plasma glucose (FPG), triglycerides, HDL cholesterol, LDL cholesterol, uric acid, high-sensitivity C-reactive protein (hs-CRP), hemoglobin A1c (HbA1c) and creatinine. Proteinuria was qualitatively measured with a dipstick. LDL cholesterol was measured using a direct surfactant method with Cholestest-LDL (Sekisui Medical Inc., Tokyo, Japan). HbA1c was measured with latex aggregation immunoassay using Determiner HbA1c (Kyowa Medex, Tokyo, Japan). The chemical assessments were all performed at BML Nagaoka (Nagaoka, Japan) except for the assessment of hs-CRP, which was performed at BML General Laboratory (Tokyo, Japan) with nephelometry using N-latex CRP-2 (Siemens Healthcare Japan, Tokyo, Japan). The measurement limit of hs-CRP was 0.02 mg/L, and a value of hs-CRP less than
- was calculated after being adjusted for age, current smoking habit, daily alcohol intake, physical activity and baseline mean blood pressure, then further adjusted for FPG, log triglycerides, HDL cholesterol and LDL cholesterol. HRs were calculated using Cox regression models in which years were used as a unit of the survival variable and the first diagnosis with hypertension in the annual health screenings was ascertained as the outcome and subjects who did not reach the outcome were censored at their last visits.

Pearson’s correlation coefficients between baseline BMI, WC and PBF and changes in them during follow-up were calculated. In subjects who did not use antihypertensive drugs at the end point (1,179 men and 788 women), Pearson’s correlation coefficients between baseline BMI, WC and PBF as well as changes in them during follow-up and changes in SBP and DBP were calculated.

All statistical analyses were performed using Dr-SPSS-2 (IBM Japan, Tokyo, Japan). P values of less than 0.05 were considered to be statistically significant.

Results

Baseline data are presented in Table 1. There was no significant difference in the baseline data between potential candidates and actual subjects. The number of subjects in normotensive men, prehypertensive men, normotensive women and prehypertensive women was 785, 436, 678 and 137, respectively. The number and cumulative incidence of hypertension for subjects with BMI ≥23 kg/m², BMI ≥25 kg/m², BMI ≥30 kg/m², WC ≥80 cm, WC ≥85 cm and WC ≥90 cm was calculated and compared with that for all subjects by χ²-squared tests. Cumulative incidence of hypertension was also calculated for quartiles of baseline BMI, WC and PBF as well as changes in BMI, WC and PBF. The BMI ≥23 kg/m² was adopted as one of the obesity categories because a study of Japanese workers reported that this category was a risk factor of hypertension.

Hazard ratios (HRs) of hypertension for prehypertension, BMI ≥23 kg/m², BMI ≥25 kg/m², BMI ≥30 kg/m², WC ≥80 cm, WC ≥85 cm, WC ≥90 cm and for each 1 unit increase in baseline BMI, WC and PBF and changes in them during follow-up as well as for the highest quartile of baseline BMI, WC and PBF and changes in them during follow-up compared with the lowest quartile were calculated after being adjusted for age, current smoking habit, daily alcohol intake, physical activity and baseline mean blood pressure, then further adjusted for FPG, log triglycerides, HDL cholesterol and LDL cholesterol. HRs were calculated using Cox regression models in which years were used as a unit of the survival variable and the first diagnosis with hypertension in the annual health screenings was ascertained as the outcome and subjects who did not reach the outcome were censored at their last visits.

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| Subject | Description |
|---------|-------------|
| | |
hypertension was 4 times higher in prehypertensive men than normotensive men and 5 times higher in prehypertensive women than normotensive women. There was no significant difference in the incidence of hypertension between any obesity category and all subjects in men while the incidence of hypertension was significantly higher in any obesity category than all subjects in women.

The cumulative incidence of hypertension in the quartiles of baseline BMI, WC and PBF as well as changes in them during follow-up are shown in Table 4. The associations between these obesity categories and incident hypertension were not significant except for a paradoxically negative association of the BMI ≥25 kg/m² category with incident hypertension in men. No significant association was found between any baseline parameters and incident hypertension while the changes in BMI, WC and PBF were significantly positively associated with incident hypertension in men. Each 1 kg/m² increase in BMI during follow-up and the highest quartile of baseline BMI compared with the lowest quartile were significantly associated with incident hypertension in women. Otherwise, no significant association was observed in women.

The further adjusted HRs of hypertension for BMI ≥23 kg/m², BMI ≥25 kg/m², BMI ≥30 kg/m², WC ≥80 cm, WC ≥85 cm, WC ≥90 cm and each 1 unit increase in baseline BMI, WC and PBF as well as changes in them during follow-up and for the highest quartile of baseline BMI, WC and PBF as well as changes in them during follow-up compared with the lowest quartile are shown in Table 4.

### Table 1 Baseline data in potential candidates and actually followed subjects

|                      | men candidates | men followed-ups | p   | women candidates | women followed-ups | p   |
|----------------------|----------------|------------------|-----|------------------|--------------------|-----|
| n                    | 1,537          | 1,221            |     | 1,086            | 815                |     |
| age (years)          | 49.5 (9.0)     | 49.5 (8.7)       | 0.940 | 49.2 (9.0)       | 49.6 (8.7)         | 0.393 |
| body mass index (kg/m²) | 22.8 (2.7)    | 22.7 (2.6)       | 0.699 | 21.3 (2.8)       | 21.3 (2.8)         | 0.799 |
| waist circumference (cm) | 83.1 (7.7)    | 83.0 (7.6)       | 0.678 | 77.8 (7.9)       | 77.8 (8.0)         | 0.874 |
| percent body fat (%)  | 21.5 (5.0)     | 21.5 (4.9)       | 0.741 | 26.2 (5.5)       | 26.2 (5.5)         | 0.996 |
| systolic blood pressure (mmHg) | 115.0 (11.7) | 115.0 (11.7) | 0.869 | 107.7 (12.0)     | 107.9 (12.0)       | 0.750 |
| diastolic blood pressure (mmHg) | 73.4 (7.6)    | 73.3 (7.6)       | 0.936 | 67.4 (7.8)       | 67.5 (8.0)         | 0.840 |
| mean blood pressure (mmHg) | 87.3 (8.7)    | 87.2 (8.7)       | 0.904 | 80.8 (8.9)       | 80.9 (9.0)         | 0.795 |
| fasting plasma glucose (mg/dL) | 93.8 (13.2)   | 93.4 (11.6)      | 0.406 | 87.8 (8.0)       | 87.9 (8.3)         | 0.646 |
| triglycerides (mg/dL) | 59 (72, 144)   | 99 (71, 141)     | 0.633 | 68.5 (53, 93)    | 70 (53, 93)        | 0.855 |
| HDL cholesterol (mg/dL) | 57.5 (14.1)    | 58.1 (14.2)      | 0.282 | 68.0 (14.6)      | 68.1 (14.8)        | 0.947 |
| LDL cholesterol (mg/dL) | 122.6 (29.5)   | 122.0 (28.8)     | 0.625 | 120.0 (30.5)     | 121.0 (30.7)       | 0.492 |
| hemoglobin A1c (%)    | 5.01 (0.45)    | 5.00 (0.39)      | 0.419 | 4.97 (0.29)      | 4.97 (0.30)        | 0.695 |
| uric acid (mg/dL)     | 6.07 (1.24)    | 6.06 (1.20)      | 0.704 | 4.38 (0.88)      | 4.40 (0.87)        | 0.588 |
| high-sensitivity CRP (mg/L) | 0.28 (0.15, 0.58) | 0.28 (0.15, 0.56) | 0.696 | 0.21 (0.10, 0.42) | 0.21 (0.10, 0.41) | 0.934 |
| eGFR (mL/min/1.73m²)  | 79.4 (12.1)    | 79.3 (12.0)      | 0.808 | 81.0 (13.1)      | 80.7 (12.9)        | 0.565 |
| current smoking       | 38.6           | 38.4             | 0.927 | 6.9              | 7.0                | 0.941 |
| daily alcohol drinking| 51.3           | 51.1             | 0.905 | 15.7             | 15.8               | 0.918 |
| physical activity     | 34.0           | 33.3             | 0.668 | 35.0             | 35.7               | 0.747 |

mean (SD) or %, eGFR: estimated glomerular filtration rate, physical activity: walking for 1 hour or longer per day or exercising for 30 minutes or longer twice or more per week

### Table 2 Cumulative incidence of hypertension in each group

|                      | men | women |
|----------------------|-----|-------|
|                      | n   | incidence (%) | p* | n   | incidence (%) | p* |
| all subjects         | 1,221 | 23.7 |     | 815 | 13.5 |     |
| normotensives        | 785  | 11.1 | <0.001 | 678 | 8.0 | <0.001 |
| prehypertensives     | 436  | 46.3 | <0.001 | 137 | 40.9 | <0.001 |
| BMI ≥ 23 kg/m²       | 536  | 27.1 | 0.130 | 207 | 21.3 | <0.001 |
| BMI ≥ 25 kg/m²       | 226  | 25.7 | 0.519 | 86  | 25.6 | 0.003 |
| BMI ≥ 30 kg/m²       | 13   | 23.1 | 0.960 | 8   | 37.5 | 0.050 |
| WC ≥ 80 cm           | 806  | 27.3 | 0.065 | 313 | 18.1 | 0.024 |
| WC ≥ 85 cm           | 483  | 28.2 | 0.054 | 161 | 21.7 | 0.007 |
| WC ≥ 90 cm           | 208  | 29.8 | 0.057 | 56  | 23.2 | 0.043 |

* compared with all subjects, BMI: body mass index, WC: waist circumference
Table 3  Cumulative incidence of hypertension in quartiles of each anthropometric parameter

|                         | Q1       | Q2       | Q3       | Q4       | p for trend |
|-------------------------|----------|----------|----------|----------|------------|
| **men**                 |          |          |          |          |            |
| **baseline BMI**        | range (kg/m²) | 15.4–20.9 | 21.0–22.6 | 22.7–24.2 | 24.3–33.6 | 0.001 |
|                         | incidence (%) | 14.9     | 26.0     | 27.5     | 26.3      |          |
| **baseline WC**         | range (cm)  | 61.6–77.7 | 77.8–83.0 | 83.1–87.9 | 88.0–110.0 | <0.001 |
|                         | incidence (%) | 15.4     | 25.9     | 21.5     | 31.4      |          |
| **baseline PBF**        | range (%)  | 5.3–18.1 | 18.2–21.4 | 21.5–24.5 | 24.6–41.8 | 0.002 |
|                         | incidence (%) | 17.3     | 23.7     | 25.6     | 28.1      |          |
| **change in BMI**       | range (kg/m²) | −12.5–−0.5 | −0.4–0.1 | 0.2–0.7 | 0.8–6.4 | 0.232 |
|                         | incidence (%) | 20.2     | 24.8     | 25.2     | 24.4      |          |
| **change in WC**        | range (cm)  | −25.7–−1.5 | −1.4–0.4 | 0.5–2.2 | 2.3–17.7 | 0.489 |
|                         | incidence (%) | 18.1     | 29.0     | 26.3     | 21.4      |          |
| **change in PBF**       | range (%)  | −18.1–−1.7 | −1.6–0.1 | 0.0–1.5 | 1.6–16.6 | 0.833 |
|                         | incidence (%) | 23.7     | 21.4     | 27.0     | 22.5      |          |
| **women**               |          |          |          |          |            |
| **baseline BMI**        | range (kg/m²) | 15.0–19.4 | 19.5–20.8 | 20.9–22.9 | 23.0–35.1 | <0.001 |
|                         | incidence (%) | 5.3      | 14.6     | 12.8     | 21.3      |          |
| **baseline WC**         | range (cm)  | 59.7–71.9 | 72.0–77.0 | 77.1–83.0 | 83.1–112.2 | <0.001 |
|                         | incidence (%) | 6.9      | 11.5     | 13.8     | 21.8      |          |
| **baseline PBF**        | range (%)  | 13.3–22.2 | 22.3–25.4 | 25.5–29.6 | 29.7–47.0 | <0.001 |
|                         | incidence (%) | 6.8      | 12.1     | 14.5     | 20.7      |          |
| **change in BMI**       | range (kg/m²) | −7.4–−0.5 | −0.4–0.1 | 0.2–0.7 | 0.8–10.8 | 0.397 |
|                         | incidence (%) | 11.2     | 14.2     | 14.4     | 14.2      |          |
| **change in WC**        | range (cm)  | −20.2–−1.4 | −1.3–0.4 | 0.5–2.3 | 2.4–27.2 | 0.274 |
|                         | incidence (%) | 10.7     | 12.7     | 17.5     | 13.0      |          |
| **change in PBF**       | range (%)  | −12.2–−1.0 | −0.9–0.5 | 0.6–2.0 | 2.1–24.3 | 0.784 |
|                         | incidence (%) | 13.6     | 13.6     | 14.5     | 12.3      |          |

BMI: body mass index, WC: waist circumference, PBF: percent body fat

Table 4  Hazard ratio of incident hypertension for each anthropometric parameter

|                         | men hazard ratio * (95% CI b) | p         | women hazard ratio * (95% CI b) | p         |
|-------------------------|--------------------------------|-----------|----------------------------------|-----------|
| **prehypertension and each obesity category at baseline** |                                |           |                                  |           |
| prehypertension          | 1.22 (0.81–1.82)              | 0.342     | 1.16 (0.63–2.16)                | 0.632     |
| BMI ≥ 23 kg/m²           | 0.84 (0.66–1.06)              | 0.143     | 1.18 (0.79–1.75)                | 0.420     |
| BMI ≥ 25 kg/m²           | 0.70 (0.52–0.94)              | 0.018     | 1.24 (0.76–2.03)                | 0.383     |
| BMI ≥ 30 kg/m²           | 0.57 (0.18–1.81)              | 0.341     | 0.89 (0.27–2.93)                | 0.853     |
| WC ≥ 80 cm               | 0.97 (0.73–1.29)              | 0.826     | 1.21 (0.82–1.78)                | 0.327     |
| WC ≥ 85 cm               | 0.91 (0.71–1.15)              | 0.411     | 1.22 (0.80–1.85)                | 0.348     |
| WC ≥ 90 cm               | 0.86 (0.65–1.15)              | 0.318     | 0.82 (0.44–1.52)                | 0.532     |
| **each 1 unit increase in parameters**                    |                                |           |                                  |           |
| baseline BMI (kg/m²)     | 0.96 (0.93–1.01)              | 0.118     | 1.03 (0.97–1.09)                | 0.371     |
| baseline WC (cm)         | 0.99 (0.98–1.01)              | 0.440     | 1.01 (0.99–1.03)                | 0.416     |
| baseline PBF (%)         | 0.99 (0.96–1.01)              | 0.351     | 1.02 (0.99–1.05)                | 0.279     |
| change in BMI (kg/m²)    | 1.26 (1.13–1.41)              | <0.001    | 1.18 (1.04–1.34)                | 0.011     |
| change in WC (cm)        | 1.08 (1.04–1.12)              | <0.001    | 1.03 (0.98–1.09)                | 0.180     |
| change in PBF (%)        | 1.09 (1.05–1.14)              | <0.001    | 1.02 (0.96–1.09)                | 0.527     |
| **the highest quartile compared with the lowest quartile** |                                |           |                                  |           |
| baseline BMI             | 1.10 (0.75–1.62)              | 0.615     | 1.21 (1.06–1.38)                | 0.005     |
| baseline WC              | 0.97 (0.66–1.41)              | 0.867     | 1.62 (0.86–3.05)                | 0.133     |
| baseline PBF             | 0.74 (0.51–1.07)              | 0.109     | 1.60 (0.84–3.04)                | 0.156     |
| change in BMI            | 2.02 (1.41–2.90)              | <0.001    | 1.32 (0.75–2.30)                | 0.337     |
| change in WC             | 1.95 (1.34–2.85)              | <0.001    | 1.24 (0.69–2.22)                | 0.478     |
| change in PBF            | 1.97 (1.37–2.83)              | <0.001    | 1.05 (0.60–1.81)                | 0.874     |

* adjusted for age, smoking, alcohol drinking, physical activity and mean blood pressure, b confidence interval, BMI: body mass index; WC: waist circumference; PBF: percent body fat
WC ≥90 cm and each 1 unit increase in baseline BMI, WC and PBF as well as changes in them during follow-up and for the highest quartile of baseline BMI, WC and PBF as well as changes in them during follow-up compared with the lowest quartile are shown in Table 5. The associations between these obesity categories and incident hypertension were not significant. No significant association was found between any baseline parameters and incident hypertension while the changes in BMI, WC and PBF were significantly positively associated with incident hypertension in men. Each 1 kg/m² increase in BMI during follow-up and the

| Table 5 | Further adjusted hazard ratio of incident hypertension for each anthropometric parameter |
|---------|--------------------------------------------------------------------------------------|
| men | women |
| hazard ratio *(95% CI) | p | hazard ratio *(95% CI) | p |
| prehypertension and each obesity category at baseline | | | |
| prehypertension | 1.17 (0.78–1.76) | 0.441 | 1.16 (0.62–2.15) | 0.640 |
| BMI ≥ 23 kg/m² | 0.87 (0.67–1.12) | 0.281 | 1.19 (0.79–1.79) | 0.394 |
| BMI ≥ 25 kg/m² | 0.74 (0.55–1.02) | 0.062 | 1.29 (0.78–2.13) | 0.328 |
| BMI ≥ 30 kg/m² | 0.66 (0.21–2.14) | 0.493 | not counted | |
| WC ≥ 80 cm | 1.07 (0.80–1.45) | 0.638 | 1.20 (0.81–1.79) | 0.367 |
| WC ≥ 85 cm | 0.99 (0.76–1.28) | 0.914 | 1.20 (0.77–1.86) | 0.417 |
| WC ≥ 90 cm | 0.94 (0.69–1.27) | 0.681 | 0.80 (0.43–1.50) | 0.489 |
| each 1 unit increase in parameters | | | |
| baseline BMI (kg/m²) | 0.98 (0.93–1.03) | 0.376 | 1.04 (0.97–1.11) | 0.250 |
| baseline WC (cm) | 1.00 (0.98–1.02) | 0.919 | 1.01 (0.99–1.03) | 0.394 |
| baseline PBF (%) | 1.00 (0.97–1.03) | 0.861 | 1.02 (0.99–1.06) | 0.214 |
| change in BMI (kg/m²) | 1.24 (1.11–1.39) | <0.001 | 1.18 (1.04–1.34) | 0.013 |
| change in WC (cm) | 1.07 (1.04–1.11) | <0.001 | 1.03 (0.98–1.08) | 0.211 |
| change in PBF (%) | 1.08 (1.04–1.14) | <0.001 | 1.02 (0.95–1.08) | 0.655 |
| the highest quartile compared with the lowest quartile | | | |
| baseline BMI | 1.06 (0.65–1.71) | 0.817 | 2.27 (1.10–4.71) | 0.028 |
| baseline WC | 1.27 (0.81–1.99) | 0.302 | 1.69 (0.87–3.29) | 0.122 |
| baseline PBF | 1.05 (0.65–1.69) | 0.852 | 2.04 (1.02–4.08) | 0.044 |
| change in BMI | 1.97 (1.36–2.85) | <0.001 | 1.31 (0.74–2.32) | 0.349 |
| change in WC | 1.84 (1.25–2.72) | 0.002 | 1.20 (0.67–2.16) | 0.546 |
| change in PBF | 1.85 (1.27–2.68) | 0.001 | 1.02 (0.58–1.78) | 0.949 |

* adjusted for age, smoking, alcohol drinking, physical activity, mean blood pressure, fasting plasma glucose, log triglycerides, HDL cholesterol and LDL cholesterol; *b confidence interval; *c the number of the subjects was too small to calculate the hazard ratio; BMI, body mass index; WC, waist circumference; PBF, percent body fat

| Table 6 | Correlation coefficients |
|---------|-------------------------|
| men | women |
| r | p | r | p |
| between change in each parameter during follow-up | | | |
| baseline body mass index | −0.153 | <0.001 | −0.099 | 0.005 |
| baseline waist circumference | −0.215 | <0.001 | −0.204 | <0.001 |
| baseline percent body fat | −0.285 | <0.001 | −0.148 | <0.001 |
| between change in systolic blood pressure during follow-up | | | |
| baseline body mass index | −0.100 | <0.001 | −0.011 | 0.765 |
| baseline waist circumference | −0.042 | 0.154 | 0.016 | 0.652 |
| baseline percent body fat | −0.074 | 0.011 | −0.019 | 0.599 |
| change in body mass index | 0.256 | <0.001 | 0.257 | <0.001 |
| change in waist circumference | 0.245 | <0.001 | 0.172 | <0.001 |
| change in percent body fat | 0.180 | <0.001 | 0.198 | <0.001 |
| between change in diastolic blood pressure during follow-up | | | |
| baseline body mass index | −0.060 | 0.038 | −0.020 | 0.581 |
| baseline waist circumference | 0.004 | 0.895 | −0.019 | 0.595 |
| baseline percent body fat | −0.032 | 0.268 | −0.049 | 0.174 |
| change in body mass index | 0.264 | <0.001 | 0.221 | <0.001 |
| change in waist circumference | 0.246 | <0.001 | 0.165 | <0.001 |
| change in percent body fat | 0.189 | <0.001 | 0.171 | <0.001 |

* excluding subjects who used antihypertensive drugs at the end point
highest quartile of baseline BMI and PBF compared with the lowest quartile were significantly associated with incident hypertension in women. Otherwise, no significant association was observed in women.

Pearson’s correlation coefficients between baseline BMI, WC and PBF and changes in themselves during follow-up and between baseline BMI, WC and PBF as well as changes in them during follow-up and changes in SBP and DBP are presented in Table 6. There were significant negative correlations between the baseline data and the changes in themselves during follow-up in both men and women. Baseline BMI and changes in SBP and DBP and baseline PBF and change in SBP were significantly inversely correlated in men. Otherwise, no significant correlation was observed between baseline parameters and changes in blood pressure. Changes in BMI, WC and PBF were significantly positively correlated with changes in blood pressure in both men and women.

Discussion

The present 5-year follow-up study demonstrated that the incidence of hypertension was 4–5 times higher in prehypertensive groups than normotensive groups. The baseline BMI, WC and PBF were not significantly associated with incident hypertension except for an inverse association between BMI ≥25 kg/m² and incident hypertension in men while changes in BMI, WC and PBF during the follow-up period were significantly positively associated with incident hypertension after being adjusted for baseline blood pressure, and the association of WC or PBF change with incident hypertension was not stronger than that of BMI change in men. In women, all the associations with incident hypertension were not significant except for positive associations between each 1 kg/m² increase in BMI during follow-up and the highest quartile of baseline BMI and PBF compared with the lowest quartile. It may, in part, be due to the insufficient sample size of women. Significant differences in the incidence of hypertension in any obesity category of women and in baseline quartiles of BMI, WC or PBF of both sexes were expired after being adjusted for baseline blood pressure. Changes in BMI, WC and PBF, but not their baseline values, were significantly positively correlated with changes in SBP and DBP during follow-up in both men and women.

These findings suggest that obese or overweight (BMI ≥25 kg/m²) individuals might make an effort to reduce their body weight to prevent hypertension. Indeed, the study population is considered to be more health conscious than the general population and obese or overweight individuals with one or more metabolic risk factors such as SBP ≥130 mmHg or DBP ≥85 mmHg were recommended to reduce their body weight after their health examinations. This intervention may explain the inverse association between the baseline BMI ≥25 kg/m² group and incident hypertension in men. However, this inverse association was not observed in women. Therefore, the above negative association between baseline obesity and incident hypertension in men may be a type 1 error due to multiple comparisons. No significant associations between baseline BMI, WC and PBF and incident hypertension was observed in women except for that of the highest quartile of baseline BMI compared with the lowest quartile.

Excess body weight and even modest adult weight gain substantially increase the risk of hypertension while weight loss reduces the risk of hypertension in female nurses in the US. Weight gain was associated with increased blood pressure and increased incidence of hypertension in white and African-American men and women adjusted for baseline BMI, height, SBP, DBP, age, waist-to-hip ratio, smoking, physical activity, education, caloric intake, fat intake and study center while weight loss was associated with a decrease in blood pressure and with a remission of hypertension in white and African-American men and women in the Atherosclerosis Risk in Communities (ARIC) studies. A study over a 5-year period in Pomerania on the southern shore of the Baltic Sea reported that a 5% weight loss reduced the risk of incident hypertension (HR, 0.84; 95% CI, 0.79–0.89) and increased the chance of incident blood pressure normalization in patients who were hypertensive at baseline by 15% (95% CI, 7%–23%)22. Another study among prehypertensive individuals reported that body weight and fat mass were markedly increased in those who developed hypertension (+5.71%; 95% CI, +4.60%–+6.83% and +17.8%; 95% CI, +14.5%–+21.0%, respectively), mildly increased in those who remained prehypertensive (+1.95%; 95% CI, +0.68%–+3.22% and +8.09%; 95% CI, +4.42%–+11.7%, respectively) and did not significantly change in those who became normotensive (−1.55%; 95% CI, −3.70%–+0.61% and +0.20%; 95% CI, −6.13%–+6.52%, respectively) after 10 years of follow-up22.

A study to test whether long-term weight change affects hypertension risk in 24,550 men and 10,111 women who were followed prospectively as part of the National Runners’ Health Study reported that the odds for hypertension were significantly related to BMI at follow-up when adjusted for baseline BMI, but generally not to baseline BMI when adjusted for follow-up BMI29. Another study investigated the obesity-hypertension link in white men over a median follow-up period of 46 years and reported that men of normal weight at age 25 years who became overweight or obese at age 45 years were at increased risk compared with men of normal weight at both times (HR, 1.57; 95% CI, 1.20–2.07), but not men who were overweight or obese at age 25 years who became normal weight at age 45 years (HR, 0.91; 95% CI, 0.43–1.92)30. These studies demonstrated a stronger association of weight change than baseline obesity or overweight with incident hypertension. In Japan, Ishikawa-Takata et al. reported that both baseline BMI and weight gain during follow-up were associated with incident hypertension in Japanese men7. Matsuo et al.27 and Tsujimoto et al.28 reported that baseline obesity is associated with incident hypertension independently of weight change during follow-up. In their secondary analysis, Tsujimoto et al. found that the HR of incident hypertension for individuals who were not obese (BMI <25 kg/m²) at baseline but obese (BMI ≥25 kg/m²) after 5 years was significantly higher compared with that for those who were not obese both at baseline and after 5-years. Conversely, the HR of incident hypertension for those who were obese at baseline but not obese after 5 years was not...
significantly higher than that for those who were not obese both at baseline and after 5-years\textsuperscript{19}. This finding suggests a stronger association of weight change than of baseline obesity with incident hypertension in Japanese.

A study investigated the effect of weight history on blood pressure in the ARIC study population and reported that the effects of a 3-year weight change history explain some of the variation in blood pressure among individuals in the same BMI category and the effects appear to be stronger and more consistent in men than in women, but generally similar regardless of current weight status\textsuperscript{19}. Another study reported that the risk of incident hypertension increased as the quartile of 2-year changes in BMI increased in men, while the BMI-gain effect on incident hypertension was not significant in women unless menopausal status was included in the adjustment\textsuperscript{19}. These gender differences are in accord with the present study results.

Limitations

This present study is a retrospective study and the subjects were not from the general population, but from a health screening population, which suggests that the study population might be more health conscious than the general population. Approximately 20% of the candidates for the follow-up survey did not participate in the follow-up survey. It is possible these people became sick or died before attending the follow-up survey. However, there was no significant difference between the baseline data in the candidates and the actual followed subjects. In this study, hypertension was diagnosed at only one time point and may have included white coat hypertension. No dietary information was available, except for alcohol intake and smoking habits. Residual confounders might have influenced the results. The number of women studied may not have been sufficient to reach a conclusive result for females. Comparisons of associations between each anthropometric parameter and incident hypertension by each 1 unit increase in BMI, WC and PBF may not be appropriate because each unit may not be equivalent. However, the association of WC or PBF with incident hypertension was not stronger than that of BMI comparing by their quartiles.

Conclusions

The present 5-year follow-up study demonstrated that the changes in BMI, WC and PBF values during follow-up rather than their baseline values were significantly associated with incident hypertension after adjusting for baseline blood pressure and that the association of WC or PBF change with incident hypertension was not stronger than that of BMI change in the health-screened men. The changes in BMI, WC and PBF, but not their baseline levels, were positively correlated with the changes in blood pressure during follow-up. These results suggest that baseline levels of BMI, WC and PBF are less important than their changes during follow-up for the prevention of hypertension. All prehypertensive individuals should restrain themselves from an excess-calorie diet regardless of their BMI and a low salt diet and increased exercise should be recommended to them.

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