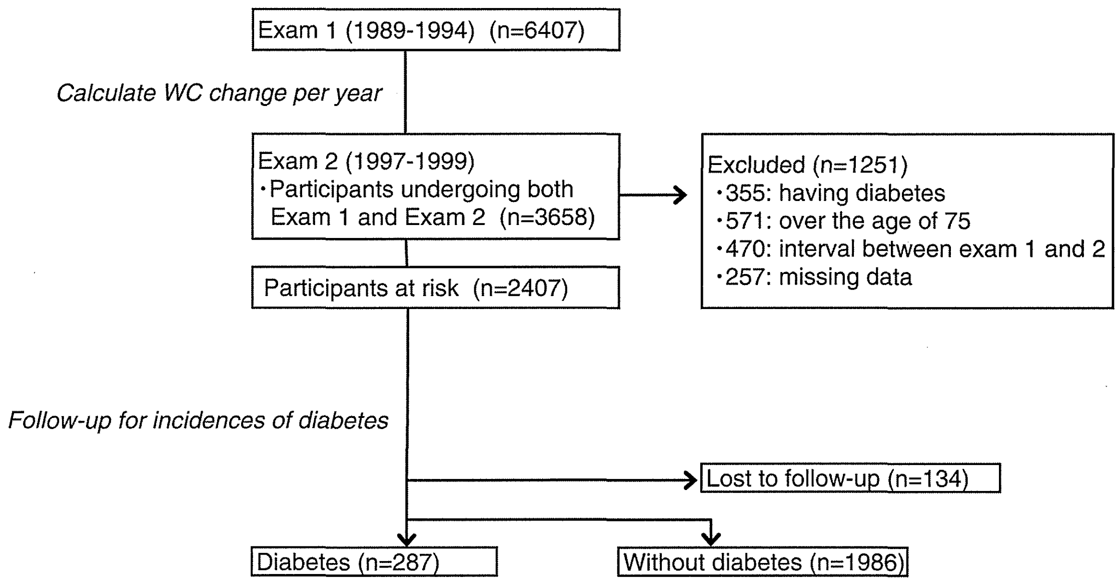

Figure 1. Process of selecting the study participants and overview of analysis of waist circumference (WC) change and the incidence of type 2 diabetes (shown in italics).

diabetes.[11] WC, an index for central obesity, is an important component in the diagnostic criteria for metabolic syndrome.[12,13] Because WC changes over the years within the same individual, in addition to assessment of the risk of type 2 diabetes based on WC at a certain point, it would be also useful to consider subsequent WC change. However, there have been just two studies on the association between WC change with the risk of type 2 diabetes, which were conducted among Iranian community residents and American health professionals.[7,14] However, percentage of visceral adipose tissue in abdominal fat is likely to differ according to race, so the impact of change in WC on type 2 diabetes could also differ from country to country.[15] This association remains unknown among the East Asians, who have a relatively low degree of obesity. In addition, it has recently also been reported that WC change does not necessarily correspond to weight change in a Chinese population.[16]

Accordingly, the purpose of this study is to investigate the association between WC change and the incidence of type 2 diabetes in an urban Japanese population, taking into consideration the influence of BMI change.

METHODS

Subjects and design

The Suita Study, a prospective population-based cohort study in an urban area of Japan, started in 1989. The details of this study have been described elsewhere.[17–19] Briefly, 6407 men and women aged 30–83 years underwent a baseline survey at the National Cerebral and Cardiovascular Center (NCVC) between September 1989 and March 1994 (examination 1 [Exam 1]) and visited the NCVC every 2 years for follow-up examinations, including blood sample testing. Of 6407 participants, 3658 underwent the follow-up examination between April 1997 and March 1999 (examination 2 [Exam 2]). Overall, 1251 participants were excluded for the following reasons: (i) having diabetes at Exam 2 ($n = 355$); (ii) age >75 years at Exam 2 ($n = 571$); (iii) the interval between Exam 1 and Exam 2 was <5 years or >9 years ($n = 470$); or (iv) missing data ($n = 257$). In addition, participants who could not be followed-up ($n = 134$) were excluded. The remaining 2273 participants were followed up from Exam 2 to the end of March 2011 (Figure 1). The Institutional Review Board of the NCVC approved this cohort study.

Data collection

Blood samples were centrifuged immediately upon collection, and a routine blood examination was performed, which included measurement of glucose levels. The Suita Study started to measure HbA_{1c} from Exam 2. The value for HbA_{1c} (%) was estimated as the National Glycohemoglobin Standardization Program equivalent value (%) calculated by the following formula: HbA_{1c} (%) = 1.02 × HbA_{1c} (Japan Diabetes Society, %) + 0.25%.[20] HbA_{1c} values are presented as percentages and SI units (mmol/mol).

Trained physicians measured blood pressure in triplicate on the right arm after 5 minutes of rest using a standard mercury sphygmomanometer. WC was measured at the umbilical level in a standing position. Participants were wearing light clothing during measurement of height and weight. BMI was calculated as weight (kg) divided by the square of height (m). Public health nurses obtained information on cigarette smoking status (current-smoker, ex-smoker, or non-smoker), alcohol drinking status (current-drinker, ex-drinker, or non-drinker) and medical histories.

Endpoint determination

Type 2 diabetes was defined as either a fasting (at least 8 hours) plasma glucose level ≥7.0 mmol/L (126 mg/dL), non-fasting plasma glucose level ≥11.1 mmol/L (200 mg/dL), HbA_{1c} ≥6.5% (48 mmol/mol),[21] or the use of antidiabetic agents. The endpoints of the present study were: (i) first diagnosis of type 2 diabetes, or (ii) March 31, 2011. Individuals not examined during follow-up were censored on the date of their last examination.

Statistical analysis

Participants were stratified by sex and median WC at Exam 1 and were additionally classified into three categories by tertile of WC change per year between Exam 1 and Exam 2. We calculated age-adjusted WC at Exam 1, Exam 2, and endpoint by sex. In addition, we assessed the correlation of changes in WC and BMI per year between Exam 1 and Exam 2.

Cox proportional hazards regression was used to estimate the adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) for the lowest and highest tertiles, with the middle tertile as the reference group. Model 1 was adjusted for age; model 2 was adjusted for age and WC at Exam 1, HbA_{1c}, family history of diabetes, and drinking and smoking status at Exam 2; and model 3 was adjusted for model 2 variables, BMI at Exam 1, and BMI change as a continuous variable. In an additional model, HRs and 95% CIs were adjusted for model 2 variables and estimated without stratification by WC at Exam 1, with the participants falling into both the WC below median and the tertile 2 in WC change groups being set as the reference group. Interactions between WC at Exam 1 (below median or ≥median) and WC change (tertiles) were tested by adding the interaction term to the model 2. All data were analyzed using SPSS statistical software (Version 20.0J; SPSS Japan Inc., Tokyo, Japan). All reported P-values are two-tailed; $P < 0.05$ was considered statistically significant.

RESULTS

The median (interquartile range) WCs at Exam 1 were 82.0 (77.0–87.0) cm in men and 75.0 (69.0–82.0) cm in women. The mean (standard deviation) interval between Exam 1 and Exam 2 was 6.8 (0.9) years. Table 1 shows characteristics at Exam 2 for men and women. WC change was considerably larger in women than men (0.51 and 0.17 cm/year, respectively). Table 2 shows age-adjusted WC at Exam 1, Exam 2, and at the endpoint examination. In the lowest tertile of WC change, WC increased from Exam 2 to the endpoint examination, regardless of sex and WC strata (WC <median or WC ≥median). Conversely, the change in WC from Exam 2 to endpoint examination in the highest tertile was stable. Figure 2 shows scatter plots of WC change and BMI change between Exam 1 and Exam 2. The correlation coefficients with a WC below the median and at the median or higher were 0.72 and 0.71 in men, respectively, and 0.39 and 0.38 in women, respectively (all $P < 0.001$).

Table 1. Characteristics of subjects at examination 2 ($n = 2273$)

	Men	Women
n	946	1327
Age, years	58.8 (10.2)	57.6 (9.7)
WC	83.5 (7.9)	79.7 (8.6)
WC change, cm/year	0.17 (0.74)	0.51 (1.05)
BMI, kg/m^2	23.2 (2.8)	22.2 (2.9)
HbA_{1c}, %, mmol/mol	5.6 (0.3), 38 (3.3)	5.6 (0.3), 38 (3.3)
Plasma glucose level, mmol/L	5.3 (0.5)	5.1 (0.5)
Systolic blood pressure, mm Hg	126.4 (18.0)	125.3 (18.9)
Diastolic blood pressure, mm Hg	80.8 (10.7)	78.6 (10.5)
Hypertension, n (%)	341 (36.0)	406 (30.6)
Total cholesterol, mmol/L	5.26 (0.81)	5.60 (0.85)
Hypercholesterolemia, n (%)	302 (31.9)	644 (48.5)
Family history of diabetes, n (%)	90 (9.5)	148 (11.2)
Smoking status, n (%)		
Current	372 (39.3)	100 (7.5)
Former	296 (31.3)	47 (3.5)
Never	278 (29.4)	1180 (88.9)
Drinking status, n (%)		
Current	690 (72.9)	411 (31.0)
Former	23 (2.4)	9 (0.7)
Never	233 (24.6)	907 (68.3)

BMI, body mass index; WC, waist circumference.
Continuous data are shown as mean (standard deviation).

During the follow-up periods (mean 9.3 [3.5] years), 287 participants developed type 2 diabetes (Figure 1). Table 3 shows multivariable adjusted HRs for incidences of type 2 diabetes according to WC change tertile. Among participants with the median WC or higher, the highest tertile had significantly higher risk for the incidence of type 2 diabetes in both sexes in model 2 (HR 1.84; 95% CI, 1.10–3.08 in men and HR 2.30; 95% CI, 1.31–4.04 in women). The lowest tertile did not have a significantly lower risk for the incidence of type 2 diabetes in either sex (HR 1.27; 95% CI, 0.73–2.21 in men and HR 1.13; 95% CI, 0.59–2.18 in women). Among participants with WC below the median, there was no significant association between WC change and the incidence of type 2 diabetes in either sex. Interactions between WC at Exam 1 (below median or ≥median) and WC change (tertiles) was not significant in men ($P = 0.395$) but was significant in women ($P = 0.011$).

Even after adjustment of BMI at Exam 1 and BMI change (model 3), these results did not change much, although the HR of the highest tertile of WC change among men with WC median or higher was borderline significant (HR 1.72; 95% CI, 0.98–3.02). In model 3, the HRs for BMI change (per 1.0 kg/m^2/year) were 2.11 (95% CI, 0.49–9.16) in men with the median WC or higher and the highest tertile of WC change and 0.93 (95% CI, 0.31–2.82) in women. In the additional model, HRs of the highest tertile of WC change significantly increased among both men and women with the median WC at Exam 1 or higher.

Table 2. Waist circumference and BMI adjusted by age at Exam 1, Exam 2, and endpoint examination (n = 2273)

	WC change		
	tertile 1	tertile 2	tertile 3
Men with WC <median[a]			
Range of WC change, cm/year	−2.556 to 0.000	0.117 to 0.552	0.558 to 2.648
Age at examination 2	59.2 (10.6)	57.0 (10.0)	57.1 (10.6)
WC, Exam 1/Exam 2/endpoint	76.9/74.2/77.6	76.3/78.4/80.2	75.9/82.9/83.9
BMI, Exam 1/Exam 2/endpoint	20.9/20.5/20.8	21.3/21.7/21.7	21.2/22.6/22.7
Men with WC ≥median[a]			
Range of WC change, cm/year	−3.598 to −0.265	−0.263 to 0.296	0.304 to 2.454
Age at examination 2	60.9 (10.4)	60.0 (8.8)	58.2 (10.1)
WC, Exam 1/Exam 2/endpoint	90.1/84.7/87.4	88.3/88.6/89.4	87.3/92.1/92.6
BMI, Exam 1/Exam 2/endpoint	24.8/23.8/23.8	24.6/24.8/24.6	24.7/25.8/25.7
Women with WC <median[a]			
Range of WC change, cm/year	−2.023 to 0.506	0.509 to 1.378	1.380 to 3.820
Age at examination 2	53.5 (9.8)	55.0 (10.3)	56.9 (8.9)
WC, Exam 1/Exam 2/endpoint	69.5/69.3/73.3	67.7/74.4/77.3	67.5/81.7/81.7
BMI, Exam 1/Exam 2/endpoint	19.7/20.3/21.2	19.6/20.7/22.2	19.7/20.8/21.9
Women with WC ≥median[a]			
Range of WC change, cm/year	−2.363 to −0.341	−0.334 to 0.463	0.472 to 3.160
Age at examination 2	60.0 (9.6)	59.5 (9.3)	60.1 (8.7)
WC, Exam 1/Exam 2/endpoint	85.3/79.4/82.9	83.4/83.8/84.8	80.8/88.4/88.5
BMI, Exam 1/Exam 2/endpoint	23.0/23.4/23.9	22.5/23.5/24.6	22.6/23.1/24.2

BMI, body mass index; WC, waist circumference.
[a]Medians of waist circumference at examination 1 were 82.0 cm in men and 75.0 cm in women. Ages are shown as mean (standard deviation).

Table 3. Multivariable adjusted hazard ratios for the incidence of type 2 diabetes according to change in waist circumference (n = 2273)

	Cases/n	IR[a]	HRs (95% CIs)			
			Model 1	Model 2	Model 3	Additional model
Men with WC <median[b]						
tertile 1	25/169	16.6	1.06 (0.59–1.90)	1.19 (0.66–2.16)	1.01 (0.52–1.96)	1.25 (0.69–2.25)
tertile 2	21/148	15.5	ref	ref	ref	ref
tertile 3	32/158	22.3	1.44 (0.83–2.49)	1.25 (0.71–2.22)	1.34 (0.73–2.46)	1.36 (0.77–2.38)
Men with WC ≥median[b]						
tertile 1	29/157	20.0	1.16 (0.68–1.99)	1.27 (0.73–2.21)	1.40 (0.75–2.58)	1.50 (0.84–2.68)
tertile 2	24/157	16.8	ref	ref	ref	1.18 (0.65–2.15)
tertile 3	39/157	29.3	1.80 (1.08–3.01)	1.84 (1.10–3.08)	1.72 (0.98–3.02)	2.22 (1.28–3.83)
Women with WC <median[b]						
tertile 1	16/213	7.9	1.70 (0.77–3.75)	1.38 (0.60–3.20)	1.98 (0.80–4.91)	1.67 (0.75–3.69)
tertile 2	10/213	4.7	ref	ref	ref	ref
tertile 3	10/213	4.7	0.93 (0.39–2.25)	0.70 (0.28–1.74)	0.52 (0.20–1.38)	0.83 (0.35–2.23)
Women with WC ≥median[b]						
tertile 1	19/229	8.6	0.90 (0.48–1.69)	1.13 (0.59–2.18)	1.24 (0.63–2.44)	1.56 (0.72–3.39)
tertile 2	20/229	9.4	ref	ref	ref	1.24 (0.57–2.69)
tertile 3	42/230	19.9	2.14 (1.26–3.65)	2.30 (1.31–4.04)	2.07 (1.13–3.79)	2.45 (1.22–4.94)

CI, confidence interval; HR, hazard ratio; Ref, reference group; WC, waist circumference.
Model 1: Adjusted by age; Model 2: Adjusted by age, HbA1c, family history of diabetes, smoking and drinking status at examination 2, and WC at examination 1; Model 3: Adjusted by model 2 variables, body mass index at examination 1, and change in body mass index as continuous variables; Additional Model: Without stratification by median of WC at exam 1 and adjusted by model 2 variables except for WC at examination 1; [a]Incidence rates/1000 person-years; [b]Medians of waist circumference were 82.0 cm in men and 75.0 cm in women at examination 1.

DISCUSSION

The present study demonstrates that, among participants with relatively high WC and regardless of sex, WC gain for 5–9 years was significantly associated with an elevated risk of incidence of type 2 diabetes for almost 10 years following WC gain, after adjustment for baseline HbA_{1c}. On the other hand, WC loss was not associated with a decreased risk of incidence of type 2 diabetes. No significant association between WC change and the incidence of type 2 diabetes was observed among individuals with relatively low WC.

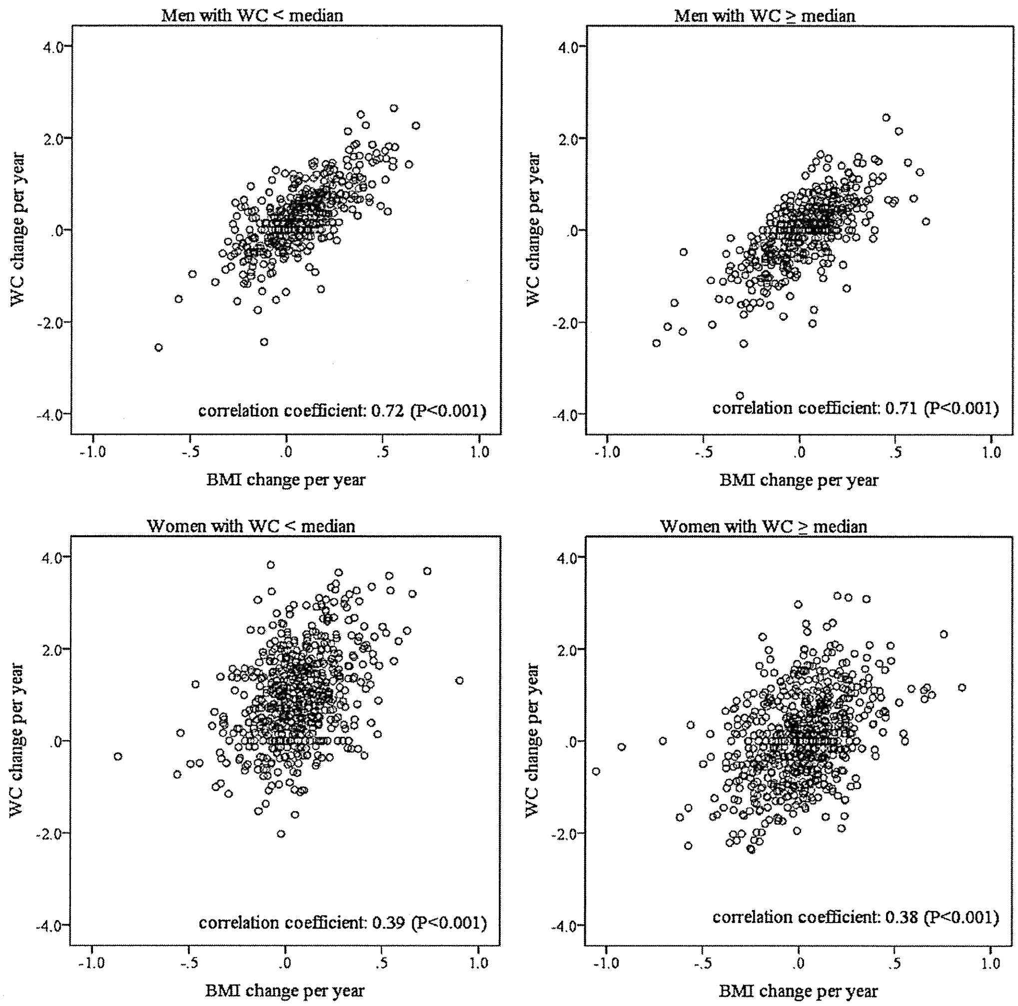

Figure 2. Scatter plots of waist circumference (WC) change and body mass index (BMI) change between examination 1 and examination 2 by sex and WC.

To our knowledge, only two studies have reported the association between WC change and type 2 diabetes. Hadaegh et al reported that WC change during 6 years of follow-up was positively associated with the elevated risk of type 2 diabetes among 4029 community residents in Iran.[14] Odds ratios were 1.6 in men and 1.5 in women per 1 standard deviation increase in WC change (5.2 cm in men and 7.7 cm in women). Koh-Banerjee et al assessed the influence of WC change in 9 years on type 2 diabetes incidences for 4 years after WC change among 22 171 male health professionals in the United States.[7] They demonstrated that men with WC gain ≥14.6 cm (1.6 cm/year) had a higher risk of developing type 2 diabetes than men who had a stable WC (relative risk 2.4; 95% CI, 1.5–3.7). Participants in these studies had higher average WC than those in the present study.[14,22] Because we also observed results similar to previous studies among participants with relatively high WC, the present results would be likely to support the previous ones, although it is difficult to compare the results between the studies because of different observation periods for WC change and ethnicities of participants.

The additional model using the six combined categories of initial WC and subsequent WC change also showed similar results. Compared to individuals with relatively low initial WC levels and subsequent mild WC gain (tertile 2), regardless of sex, WC gain was significantly associated with increased risk of type 2 diabetes only among individuals with relatively high WC levels, while no significant association was observed in other categories. This indirectly suggests that it might be important to combine WC at a certain point and subsequent WC change for estimation of risk of diabetes.

However, an observational study has reported that WC loss was not associated with a decreased risk of type 2 diabetes incidence.[7] In the present study, the effect of WC loss among participants with relatively high WC was not observed, although it is not clear whether WC loss was caused by participants' effort, such as lifestyle changes. Among individuals in the lowest tertile whose WC decreased from Exam 1 to Exam 2 (a 5.4-cm decrease in men with relatively high WC and a 5.9-cm decrease women with relatively high WC), WC increased after Exam 2 (a 2.7-cm increase in men with a relatively high WC and a 2.5-cm increase in women with relatively high WC) (Table 2). In other words, WC showed a U-shaped change from Exam 1 to the endpoint examination, and it can be inferred that the risk of type 2 diabetes might not decrease merely because of WC gain after Exam 2.

Koh-Banerjee et al reported that men with WC gain had a higher risk for type 2 diabetes incidence after adjustment for weight change.[7] Similarly, in the present study, WC change was associated with the incidence of type 2 diabetes almost independently of BMI change among both men and women with relatively high WC levels, although this relationship was more evident in women. On the other hand, BMI change was not associated at all. The present study suggests that WC change should be considered prior to weight change to estimate the risk of type 2 diabetes, especially in Japanese women. In addition, the results of the correlation analyses showed that WC change was much more strongly correlated with BMI change in men than women. This difference in correlation could be involved in the sex difference. Because body fat distribution differs considerably between age groups, sexes, and ethnicities,[23,24] it would be necessary to take these factors into consideration when combining WC and BMI to estimate the risk of type 2 diabetes.

The present study has several limitations. First, 62.0% of participants did not undergo Exam 2 under fasting conditions (≥8 hours), although almost all underwent Exam 1 under fasting conditions. However, there was no significant difference in fasting status among the tertiles of WC change regardless of sex and WC strata, and the time after a meal was ≥5 hours in 87% of participants. Such random misclassifications by measurement error might lead to underestimation of the real relationship (toward the null) between WC changes and the risk of diabetes. Second, the correlation coefficients between change in WC and BMI were high in men (0.71–0.72), so the presence of co-linearity might influence the adjusted HRs in model 3 of Cox proportional hazards regression. However, since the HRs did not change much after adjustment for BMI changes, we think the influence of co-linearity was likely to be limited. Third, single assessment of WC change may lead to underestimation of the relationship between WC change and type 2 diabetes incidences due to regression dilution bias.[25]

In conclusion, WC gain was significantly related to an increased risk of type 2 diabetes in both sexes with a higher WC. In terms of diabetes prevention, it is important to avoid WC gain, especially among men and women with relatively high WC. In addition, assessing WC change may be important than assessing BMI change in estimating the risk of type 2 diabetes, especially in the Japanese women.

ONLINE ONLY MATERIAL

Abstract in Japanese.

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Conflicts of interest: None declared.

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Interaction of Blood Pressure and Body Mass Index With Risk of Incident Atrial Fibrillation in a Japanese Urban Cohort: The Suita Study

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BACKGROUND AND PURPOSE

To prevent stroke, strategies for atrial brillation (AF) prevention and an early detection of AF by electrocardiogram are essential. However, only a limited prospective studies have examined the risk factors for AF, even in blood pressure (BP) and body mass index (BMI), which are not clear among general populations. We investigated the impacts of BP and BMI on the risk of incident AF in a general population.

METHODS

A total of 6,906 participants (30–84 years) in the Suita Study were prospectively followed up for incident AF. Participants were diagnosed with AF if AF or atrial utter was present on an electrocardiogram from a routine health examination (every 2 years) or if AF was indicated as a present illness from health examinations and/or medical records during follow-up. Adjusted Cox proportional hazard ratios (HRs) were calculated.

RESULTS

During the 12.8-year follow-up, 253 incident AF events occurred. Compared with the systolic BP (SBP) < 120 mm Hg and normal-weight, the adjusted HRs (95% con dence intervals; CIs) of incident AF in the systolic hypertension and the overweight (BMI 25 kg/m^2) groups were 1.74 (1.22–2.49) and 1.35 (1.01–1.80), respectively. Compared with SBP < 120 mm Hg and normal weight, the adjusted HRs (95% CIs) of incident AF in the SBP = 120–139 mm Hg with overweight and the systolic hypertension with normal or overweight were 1.72 (1.01–2.91), 1.66 (1.10–2.50), and 2.31 (1.47–3.65), respectively (*P* for interaction = 0.04).

CONCLUSIONS

Systolic prehypertension and overweight are associated with incident AF in Japanese population. The association between SBP and AF may be evident by overweight.

Keywords: atrial brillation; blood pressure; body mass index; hypertension; prospective cohort study; risk factor.

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Atrial fibrillation (AF) is the most common chronic arrhythmia and is a risk factor for all-cause mortality[1] and stroke.[2] To prevent stroke, strategies for AF prevention and an early detection of AF by electrocardiogram are essential. However, only a limited number of prospective studies have examined the risk factors for AF among general populations.

Recent studies have gradually revealed that not only hypertension,[3,4] but also prehypertension is a risk factor for incident AF.[5,6] Pulse pressure is also a risk factor for incident AF.[7] However, it is still difficult to determine which blood pressure (BP) categories associated with incident AF in prospective studies.[8] It may be dependent on the different backgrounds of populations, lifestyles, and/or cardiovascular risk factors[9] such as obesity.

Positive associations with incident AF have been observed for overweight[10] and class 1[11,12] or 3[13] obesity. These different results may depend on the different backgrounds of the study populations. The combined impact of obesity and should also be considered regarding the incidence of AF. However, few prospective studies have examined the combined effect of BP and BMI on the incidence of AF in a general population. Only the Women's Health Study showed no interaction between hypertension and obesity in incident AF.[14] Different populations may have different incidence rate of AF,[15] and therefore possibly different risk factors for AF. Here, we assessed the hypothesis that the combination of BP and BMI categories increases the risk of incident AF in an urban general Japanese population, which has higher BP and less obesity than Westerners.[9]

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METHODS

Study participants

The design and selection criteria of the Suita Study have already been described.[16] As a baseline, 12,200 and 3,000 participants (aged 30–79 years) were randomly selected from the municipality population registry of Suita city and stratified into groups by sex and age in 10-year increments in 1989 and 1996, respectively. Of these, participants attending the baseline examination of the original cohort (n = 6,485; 1989–1996) and the secondary cohort (n = 1,329; 1996–1998) were eligible for the present investigation. In addition, the baseline examination of a volunteer group (n = 546, 1992–2006) was also included in the present study. Informed consent was obtained from all participants. These evaluations are referred to as the baseline examination for the present investigation. This study was approved by the Institutional Review Board of the National Cerebral and Cardiovascular Center, Suita, Japan.

We excluded participants for the following reasons: prior or current illness of AF or atrial flutter (n = 42) at baseline, missing covariate (n = 2), and failure to complete the baseline examination (n = 2) or the follow-up health surveys (n = 1,408), resulting in a sample of 6,906 participants.

Blood pressure and physical measurement

In National Cerebral and Cardiovascular Center, well-trained physicians measured each participant's BP 3 times using a mercury column sphygmomanometer, an appropriate-size cuff, and a standard protocol.[16] Before the initial BP reading was obtained, participants were seated at rest for at least 5 minutes. BP values were taken as the average of the second and third measurements, which were recorded more than 1-minute apart. At the time of the baseline examination, each participant was classified into 1 of 3 BP categories (normal BP (<120/80 mm Hg), prehypertension (120–139/80–89 mm Hg), and hypertension (≥140/90 mm Hg and/or antihypertensive drug use)). If the systolic BP (SBP) and diastolic BP (DBP) readings for participants were in different categories, the participants were categorized into the higher of the 2 BP categories. SBP and DBP alone categories were as follows: normal (<120/80 mm Hg), systolic and diastolic prehypertension (120-139/80-89 mm Hg), and hypertension (≥140/90 mm Hg including antihypertensive drug users), respectively. Categories of body mass index (BMI), calculated as weight (kg) divided by height (m) squared, were defined by the following criteria: underweight (<18.5 kg/m^2), normal weight (18.5 to <25 kg/m^2), and overweight (≥25 kg/m^2).[17]

Biochemical measurement and questionnaire

At the baseline examination, we performed routine blood tests that included serum total cholesterol and glucose levels. Hypercholesterolemia was defined as total cholesterol levels ≥5.7 mmol/L or current use of antihyperlipidemic medications. Diabetes (DM) was defined as fasting serum glucose ≥7.0 mmol/L, nonfasting serum glucose ≥11.1 mmol/L, or medications for DM. Physicians and nurses administered questionnaires covering personal habits and present illness. Past/present illness of stroke included cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage. Past/present illness of heart disease included coronary heart disease, valvular disease, and chronic heart failure. Premature contractions consisted of frequent atrial, junctional, and/or ventricular premature beats (Minnesota Code 8-1-1, 8-1-2, or 8-1-3) without AF/flutter at the baseline. The glomerular filtration rate (mL/min/1.73 m^2) of each participant was calculated using the Modification of Diet in Renal Disease equation modified by the Japanese coefficient (0.881), as follows: glomerular filtration rate = $0.881 \times 186 \times (\text{age})^{-0.203} \times (\text{serum creatinine})^{-1.154}$ (×0.742 for women).[18] Chronic kidney disease was defined as an estimated glomerular filtration rate <60 mL/min/1.73m.[2]

Definition of AF and follow-up

Standard 12-lead electrocardiograms were obtained from all participants in the supine position. Each record was coded independently using the Minnesota Code by 2 well-trained physicians. Participants were diagnosed with AF if AF (Minnesota Code 8-3-1) or atrial flutter (Minnesota Code 8-3-2) was present (n = 170) on an electrocardiogram from the routine Suita health check-up examination (every 2 years) or if AF was indicated as a present illness by the health check-up examination (n = 46), and hospital medical records (n = 33), and/or death records (n = 4) during follow-up. The end point of the follow-up period for each participant was whichever of the following options occurred first: (i) the date of the first AF event, (ii) date of the last health examination and medical records, and (iii) May 31, 2013 (censored).

Statistical analysis

We examined the association between BP or BMI categories and the risk of incident AF using multivariable-adjusted Cox proportional hazard regressions after adjusting for sex and age in 5-year increments as stratified variables, BMI (underweight, normal weight, and overweight) or BP (normal BP, prehypertension, and hypertension), and other potential confounding factors at the baseline survey: namely, hypercholesterolemia, DM, and current smoking and drinking, respectively (Model 1). For Model 2, further confounding variables were used for cohort groups, chronic kidney disease, histories of stroke, coronary heart disease, chronic heart failure, and premature contractions in addition to those in Model 1 (Model 2). The Cox proportional hazard ratios (HRs) and 95% confidence intervals (95% CI) were fitted to the combination of the BP and BMI categories after adjusting for sex and age in 5-year increments as stratified variables and other potential confounding factors. We tested for interactions term generated by SBP × BMI strata in the Cox model adjusting for Model 2. We tested for interactions between follow-up year and BP or BMI to determine whether the assumption of proportional hazards for prediction of AF was valid. All analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

The baseline characteristics of the study participants grouped according to the SBP and BMI categories are presented in Table 1. At the baseline survey, the participants with systolic hypertension and overweight tend to be older, had higher prevalence of DM and hyperlipidemia, histories of stroke and heart disease, and had a lower frequency of current smoking compared to the participants with normal SBP and underweight, for both men and women. The baseline characteristics according to the 3 cohort groups (original, secondary, and volunteer) are shown in Supplementary Table I, which provides the details of participants' baseline characteristics.

During the 12.8 years of follow-up, 253 incident AF events occurred. There was no interaction between follow-up year and BP for prediction of AF in the primary Cox model, suggesting that the proportional hazards assumption was appropriate. Compared with the normal ranges of BP categories and pulse pressure <40 mm Hg, the risks of incident AF were increased in the participants with systolic and diastolic hypertension, hypertension, and pulse pressure ≥60 mm Hg, respectively adjusting for age and sex, and Models 1 and 2 (Table 2). Systolic hypertension is a risk factor of AF in men (HR = 1.65 and 95% CI = 1.07–2.56) and women (HR = 1.93 and 95% CI = 1.03–3.65, data not shown). After further adjustment by DBP, a significant association was still observed in systolic hypertension (HR = 1.74 and 95% CI = 1.12–2.69). However, the influences of DBP and pulse pressure were attenuated after adjustment for SBP. When antihypertensive medication users were classified into their BP levels, the risks of AF according to BP categories were similar (Model 2-adjusted HRs and 95% CI in SBP: 1.72 and 1.20–2.48 for systolic hypertension, data not shown).

Compared with the normal weight participants, the adjusted risks of incident AF were increased in the overweight participants after adjustment for age and sex, in Models 1 and 2, and even after adjustment for both SBP and DBP (Table 3).

After adjustment in Model 2, each 1-unit increase in SBP, DBP, pulse pressure, and BMI were associated with increases in the risk of AF. Among BP variables, after the further adjustment by BPs, only SBP was observed to increase the risk of AF (Table 4). The results in men and women separately were weak due to the small sample sizes, but were marginally or statistically significant (Supplementary Table II). After the adjustment by Model 2 plus SBP and DBP, a 5% increased risk of incident AF by 1 kg/m^2 increase in BMI was revealed.

Compared with SBP < 120 mm Hg and normal weight, the adjusted HRs (95% CIs) of incident AF in the SBP = 120–139 mm Hg participants with overweight and the systolic hypertension participants with normal weight or overweight were 1.72 (1.01–2.91), 1.66 (1.10–2.50), and 2.31 (1.47–3.65),

Table 1. Baseline characteristics according to categories of systolic blood pressure and body mass index

	Systolic BP categories[a]			Body mass index categories[b]		
	Normal SBP	Systolic prehypertension	Systolic hypertension	Underweight	Normal weight	Overweight
Number, *n*	2,697	2,201	2,008	548	4,960	1,398
Sex (men, %)	42.3	50.7	50.3	36.2	46.8	51.9
Age, year	49.3 ± 12.3	56.9 ± 11.7	63.5 ± 9.6	56.2 ± 14.8	55.6 ± 12.7	56.7 ± 12.0
Systolic BP, mm Hg	107.1 ± 7.8	128.8 ± 5.7	153.2 ± 16.8	119.4 ± 23.1	126.3 ± 21.1	134.6 ± 21.3
Diastolic BP, mm Hg	69.0 ± 7.8	79.9 ± 8.3	87.8 ± 11.7	71.4 ± 11.9	77.2 ± 11.6	83.2 ± 12.0
Body mass index, kg/m^2	21.7 ± 2.8	22.8 ± 2.9	23.4 ± 3.3	17.4 ± 1.0	21.9 ± 1.7	27.1 ± 2.1
Hypertension, %	0.3	10.9	100.0	20.0	29.7	48.1
Diabetes mellitus, %	2.6	5.0	8.3	3.1	4.1	8.9
Hyperlipidemia, %	28.8	40.5	44.9	36.5	36.4	44.4
Chronic kidney disease, %	6	9	13	9	8	10
Current smoking, %	31.7	27.9	23.7	30.1	28.4	26.4
Current drinking, %	49.7	53.1	49.5	41.6	51.5	51.6
History of stroke, %	0.4	1.0	3.5	1.6	1.4	2.0
History of heart disease, %	0.7	2.1	4.0	1.3	2.1	2.7
Premature contractions, %[c]	1.6	2.3	3.6	3.6	2.3	2.2

Abbreviation: SBP, systolic blood pressure.

[a]Normal SBP, SBP < 120 mm Hg; systolic prehypertension, SBP = 120–139 mm Hg; systolic hypertension, SBP ≥ 140 mm Hg and/or antihypertensive drug users.

[b]Body mass index was categorized by the following criteria: underweight, <18.5 kg/m^2; normal weight, 18.5 to <25 kg/m^2; and overweight, ≥25 kg/m^2.

[c]Premature contractions consist of premature atrial and/or ventricular contractions without atrial fibrillation/flatter at the baseline.

Table 2. Multivariable-adjusted hazard ratios (95% confidence intervals) of incident atrial fibrillation according to the various blood pressure categories

SBP	Normal SBP	Systolic prehypertension	Systolic hypertension	Trend *P*
Person years	37,548	28,607	22,503	
Cases	53	83	117	
Incidence/1,000 person-year	1.41	2.90	5.20	
Age- and sex-adjusted	1	1.34 (0.94–1.91)	1.90 (1.34–2.69)	<0.001
Model 1 adjusted	1	1.31 (0.92–1.87)	1.80 (1.26–2.57)	<0.001
Model 2 adjusted	1	1.29 (0.91–1.85)	1.74 (1.22–2.49)	0.002
Model 2 and DBP adjusted	1	1.29 (0.88–1.90)	1.74 (1.12–2.69)	0.010

DBP	Normal DBP	Diastolic prehypertension	Diastolic hypertension	Trend *P*
Person years	48,459	20,950	19,249	
Cases	98	63	92	
Incidence/1,000 person-year	2.02	3.01	4.78	
Age- and sex-adjusted	1	1.22 (0.88–1.68)	1.64 (1.23–2.20)	<0.001
Model 1 adjusted	1	1.18 (0.85–1.64)	1.51 (1.11–2.05)	0.008
Model 2 adjusted	1	1.16 (0.84–1.61)	1.47 (1.08–1.99)	0.014
Model 2 and SBP adjusted	1	1.03 (0.73–1.46)	1.14 (0.77–1.69)	0.513

Blood pressure category	Normal BP	Prehypertension	Hypertension	Trend *P*
Person years	33,751	29,093	25,814	
Cases	50	81	122	
Incidence/1,000 person-year	1.48	2.78	4.73	
Age- and sex-adjusted	1	1.25 (0.87–1.80)	1.70 (1.20–2.40)	0.002
Model 1 adjusted	1	1.22 (0.84–1.75)	1.58 (1.11–2.26)	0.008
Model 2 adjusted	1	1.20 (0.83–1.73)	1.53 (1.07–2.19)	0.016

Pulse pressure	<40 mm Hg	40 59 mm Hg	≥60 mm Hg	Trend *P*
Person years	27,639	44,938	16,053	
Cases	41	121	90	
Incidence/1,000 person-year	1.48	2.69	5.61	
Age- and sex-adjusted	1	1.25 (0.87–1.81)	1.78 (1.19–2.67)	0.003
Model 1 adjusted	1	1.29 (0.89–1.86)	1.78 (1.18–2.67)	0.004
Model 2 adjusted	1	1.29 (0.90–1.87)	1.75 (1.17–2.64)	0.005
Model 2 and SBP adjusted	1	1.14 (0.76–1.70)	1.28 (0.73–2.25)	0.399

Abbreviations: BP, blood pressure; DBP, diastolic blood pressure; SBP, systolic blood pressure.
Model 1: Adjusted by age, sex, body mass index, hypercholesterolemia and diabetes, current smoking and drinking status.
Model 2: Adjusted by Model 1 factors, cohort groups, chronic kidney disease, and histories of stroke, coronary heart disease, chronic heart failure, and premature contractions.

respectively (*P* for interaction between SBP and BMI = 0.04, Figure 1).

DISCUSSION

Our findings indicated that systolic and/or diastolic hypertension, higher pulse pressure, and overweight are risk factors for incident AF. Among these various components of BPs, only systolic hypertension was an independent predictor of incident AF after further adjustment. Overweight also remained a significant factor after further adjustment by both SBP and DBP. Interaction of SBP and BMI with risk of incident AF was observed. Hence, to our knowledge, this is the first positive association on the interaction of SBP and BMI with risk of incident AF in a general population.

In the Women's Health Study, high-normal SBP and DBP were associated with incident AF,[5] and after further

Table 3. Multivariable-adjusted hazard ratios (95% confidence intervals) of incident atrial fibrillation according to body mass index categories

[illegible]

adjustment of both SBP and DBP, systolic hypertension was still associated with incident AF, but DBP was attenuated, which was similar to the current study. In a healthy Norwegian cohort study in men, the upper-normal SBP (128–138 mm Hg) and DBP (≥80 mm Hg) had 2- and 1.7-folds increased risk of incident AF, however, did not reveal an association between pulse pressure and incident AF.[6]

The Framingham Heart Study showed that a 20-mm Hg increase in pulse pressure was associated with a 1.26-increased risk of AF.[7] SBP was positively associated with AF, but when DBP was added in this model, only pulse pressure still consistent with AF. In our study, high pulse pressure (≥60 mm Hg) and diastolic hypertension were associated with incident AF. However, after further adjustment for SBP, the associations were attenuated. The difference in these results might be due in part to the body composition (mean BMI = 22.5 and 25.7 kg/m^2 in Japanese and U.S. populations, respectively). Increasing BMI is a strong risk factors for ventricular diastolic dysfunction[19] and increasing pulse pressure.[20] Previous Japanese prospective studies show that SBP is the highest important predictor of incident cardiovascular disease, among the various BP variables, but pulse pressure is less important.[21] Compared with normal BP group, controlled hypertension group does not increased risk of incident AF. However, uncontrolled hypertension is a risk factor for incident AF (HR = 1.53, 95% CI = 1.06~2.21, Supplemental Table III). Controlled hypertension is important to prevent AF. Arterial stiffness, left ventricular hypertrophy, and increased left atrial size are important mediators of the relationship between BP and incident AF.[22]

We found that overweight was linked to a 1.35-fold increased risk of incident AF in this population, and still associated with incident AF after adjustment for both SBP and DBP. In previous cohort studies, the increased risks of incident AF were observed in obese,[11,12,14] and in overweight.[14] The previous cohort studies showed around 4–5% increased risk of each 1-kg/m^2 increase in BMI,[11,12,14] which is compatible with the results of our study. Recently, a Japanese cohort study has shown that obesity was a 2.2-fold increased risk of incident AF,[23] but nonassociations with overweight and hypertension were observed. Due to the low frequency of our obese subjects (1.6%), we could not calculate the risk of AF associated with obesity.

Increasing body weight has an important association with left atrial enlargement,[24] because it causes left ventricular hypertrophy[25] and elevated blood flow volume,[26] and increases the vulnerability of the atrium that triggers

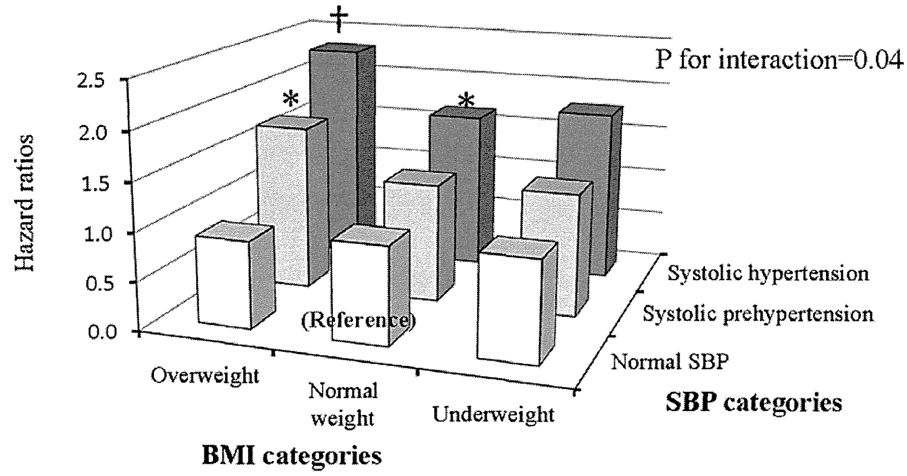

Figure 1. Multivariable-adjusted hazard ratios of incident atrial brillation according to combinations of systolic blood pressure (normal SBP and systolic prehypertension and hypertension) and body mass index (underweight, normal weight, and overweight) categories. Data are expressed as multivariable-adjusted hazard ratios adjusted for Model 2. **P* < 0.05, compared with normal weight and normal SBP as references. †*P* < 0.001, compared with normal weight and normal SBP as a reference. Abbreviations: BMI, body mass index; SBP, systolic blood pressure.

AF.[27] The pathogenesis of increasing body weight is related to increasing BP,[28] and involves metabolic dysregulation,[29] the sympathetic nervous system,[30] renin-angiotensin-aldosterone system activity,[31] and renal sodium reabsorption.[32] In the present study, we observed an interaction between BMI and BP for incident AF. Weight gain has previously been associated with left ventricular hypertrophy[25] and an increased risk of hypertension.[28] Participants with both higher SBP and overweight may experience the mutual exacerbation of left ventricular hypertrophy and hypertension, and consequently, a synergistically increased risk of AF.

Our study has several limitations. The primary limitation is a dilution bias; this study was based on a baseline survey of BP and BMI, which may have led to a misclassification of these risk factors for AF. A previous study has suggested, however, that BP measurements taken on a single day are accurate.[33] Second, we did not perform Holter electrocardiography cyclopedically, even if we perform Holter electrocardiography, we may have missed participants with paroxysmal AF. Third, even with the moderate sample size and 12.8-year follow-up, the numbers of incident AF were limited. A study with a larger sample size is required to validate to the associations. Fourth, 1,408 participants without follow-up were excluded from our baseline data. Compared with the followed-up subjects, the subjects without follow-up had higher percentage of men and smoking and higher prevalence of hypertension, DM, and hyperlipidemia. However, the prevalence of AF at the baseline was not significant in the 2 groups (Supplemental Table IV). Fifth, we did not use follow-up data of BMI and BP, but baseline data. We can predict the future AF by healthy examinations as a baseline in this study. Near future, we will conduct the different study using updated measures to account for changes in BMI over time frame and to characterize the short-term impact that BMI could have on AF risk, and even how weight-loss and -gain influence on BP level. Finally, we did not have types of antihypertensive agents at the baseline.

In conclusion, hypertension and overweight are important risk factors for incident AF. Interaction of these 2 risk factors with risk of incident AF was observed. For AF prevention, it is important to not have these 2 risks. For early detection of AF, it is also important for a person with those 2 risk factors to take an electrocardiogram regularly.

SUPPLEMENTARY MATERIAL

Supplementary materials are available at *American Journal of Hypertension* (http://ajh.oxfordjournals.org).

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DISCLOSURE

The authors declared no conflict of interest.

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特別寄稿

データヘルス計画に一歩踏み出そう

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はじめに

データヘルス計画作成の説明会で全国をまわると、「データ分析の専門家がいないと取り組めない」「新しい事業をやらなければ…」といった声をうかがいます。もしかすると、比較的多くの保険者の皆さんがデータヘルス計画の“罠”にはまっているのかもしれません。

1. 健康課題の抽出

データは分析することが目的ではなく、データを“読む”ことで地域の健康課題を抽出することがポイントです。

新城市ではレセプトから循環器や新生物の医療費が高い状況が把握されました（7月号）。当市では住民の高齢化が高額医療費に寄与していることが予想されましたが、特定健診データを“読む”ことで若年でも脂質、血糖が県平均を上回っており、高齢化だけが高医療費の背景ではないことがわかりました。そうすると、当市では高齢者の高血圧対策に加えて、若年層で醸成されるメタボリック・シンドロームも重要な健康課題と位置づけることができます。

また、豊川市では特に血糖が高いという背景に、地域の食（果物）文化がある可能性が専門職から指摘されました。これは、レセプトや健診データからだけではわからない、日頃の保健師活動で地域の様子を熟知しているからこそ、データの背景を“読む”ことができるわけです（9月号）。

被保険者の年齢構成や生活習慣、産業構造、自治会・JA等の活動といった地域の状況とレセプト・健診データで得られた特徴を併せることで、健康課題が見えやすくなります。

2. 既存事業をベースにした組み立て

データヘルス計画では、PDCAをまわして事業効果をあげます。したがって、実績がある既存事業を活用すれば、運営が難しいポイントや効果を測るタイミングがわかりやすいというメリットがあります。たとえば、これまで取り組んだ特定保健指導でリバウンドが多いことがわかれば、行動計画の内容と次年度の健診結果を併せてチェックすることで、初回面接時の支援の工夫が見えてきます。ウォーキングプログラムの参加者がいつも同じであれば、データヘルス計画で導入される健診結果に基づく「情報提供」（被保険者への意識づけ）と同時にプログラムのPRをすることで、自らの健診結果を理解した被保険者の参加が増えるかもしれません。

新規事業はお金だけでなく、関係機関との調整に時間を要し、対象者の反応もわからないことから、データヘルス計画の第一歩は既存事業を活用することが有用です。

3. 目標および評価指標はセットで設定する

健康課題に応じて保健事業の目的を決めたら、その目的を達成するための目標を設定します。目標によって事業の対象や方法、評価指標は異なってきます。

たとえば、若年から血圧が高く、中高年の循環器の医療費が高い地域で高血圧対策を保健事業の中核に位置付けている国保のケース。

脳卒中など循環器疾患の重症化予防（低減）を目標とする場合、未治療者への受診勧奨に加え、患者の血圧管理が重要となることから、医療機関と連携しながら事業を進めます。医師会等との情報共有が進んだ段階では、主治医から必要性の高い患者に「高血圧教室」や「栄養指導」への参加勧奨をしてもらうことが有効です。この場合、アウトプット指標として連携医療機関数、教室・指導への参加者数、アウトカム指標として参加者の血圧コントロール率（短期）、脳卒中の新規発症率（長期）などが挙げられます。

一方、住民（被保険者）の高血圧予防（低減）を目標に掲げると、特定健診の受診を一層促しながら、健診受診者に自らのリスクを理解してもらうための「情報提供」や、リスク改善を図る「特定保健指導」が重要な事業となります。この場合、アウトプット指標として「情報提供」「特定保健指導」の実施数、アウトカム指標として健診結果の理解率、指導参加者の改善率（短期）、住民全体の高血圧の有所見率（長期）などが考えられます。

おわりに

データヘルス計画に取り組むことを通じて、地域の状況を庁内外関係者で共有し、ともに対策を考える機会にしていただければと思います。

Profile

古井　祐司

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東京大学医科学研究所、同大学医学部附属病院などを経て、平成16年同大学附属病院22世紀医療センター助教、ヘルスケア・コミッティー株式会社代表取締役就任。東大病院では国立大学の法人化の流れの中で、産学連携のもとで予防医学の研究・教育を担う22世紀医療センターの創設に関わる。同時期に健康委員会（ヘルスケア・コミッティー）を株式会社化し、医療保険者の保健事業を受託しながら、産官学での予防医学研究を進める。平成24年からは健康経営を普及する研究拠点を同大学政策ビジョン研究センター内に創設、同助教就任。厚生労働省、経済産業省、自治体、保険者団体などで委員を務める。専門は予防医学、保健医療政策。

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Changes in Walking Styles in the Elderly after the Presentation of Walking Patterns

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Abstract

FURUI, Y., KIM, H., MITSUYA, Y., TAKAYANAGI, N., MIYANAGA, M., SUDO, M., NIKI, Y. and TOKIMITSU, I. Changes in Walking Styles in the Elderly after the Presentation of Walking Patterns. Adv. Exerc. Sports Physiol., Vol.21, No.3 pp.59-65, 2015. In order to promote the health of the elderly, it is important to maintain and improve their physical activities. To improve and maintain daily walking in the elderly, this study examined changes in the status of walking in daily life, including the daily number of steps and the activity levels, and walking styles, including walking pattern parameters (walking speed, step length, step width, walking angle, and cadence), by a walking support program. The program consisted of the following: 1) information provision through health seminars, 2) daily walking guidance based on the status of daily walking clarified through measurement using an accelerometer, 3) walking style guidance based on walking patterns using a plate sensor, and 4) walking style guidance based on changes in walking patterns after the completion of the program. Twenty-seven elderly community residents aged 60 or over completed the program. It was implemented for 7 weeks. In addition, follow-up measurement was performed 10 weeks after the termination of the program to examine the duration of its effects. In a comparison of the data obtained with the accelerometer before and after daily walking guidance, significant increases in the number of steps and the activity levels were observed after walking style guidance. Positive effects were also observed in the parameters of walking speed, step length, step width, and walking angle after guidance; in particular, regarding step length and walking angle, the effects were marked even 10 weeks after the termination of the program. Furthermore, body composition analysis revealed a significant increase in skeletal muscle mass. These results indicate that the program is useful in terms of health promotion of the elderly.
Keywords: Walking guidance, walking styles, health promotion, programs, elderly

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Introduction

For the elderly, it is important to actively perform physical activities, such as stretching, walking, and low-intensity sports, in order to prevent lifestyle-related diseases and decreased activities of daily living (ADL) (16). Among such activities, walking is being performed the most actively in daily life; in fact, it has been reported that the majority of those in their fifties and sixties perform it as a daily health-promoting activity (23).

On the other hand, in a survey conducted as part of the national program Health Japan 21, the mean daily numbers of steps for male and female adults were 8,202 and 7,282, respectively, indicating that target values (9,200 and 8,300 steps/day, respectively) had not been achieved. The elderly aged 70 or over showed a similar tendency; the mean daily numbers of steps for males and females were 5,436 and 4,604, respectively, while target values for them were 6,700 and 5,900 steps/day, respectively. Based on these results, the necessity of making further efforts to develop appropriate walking habits was emphasized.

In previous studies examining walking patterns in the elderly, decreases in walking speed, step length, and cadence and increases in step width, walking angle, and duration of the double supporting period have been frequently noted (5,14). Such patterns may be explained by age-related decreases in muscle strength and agility (22). In recent years, walking speed has been increasingly focused on as an index representing walking functions, and decreased walking speeds have been reported to be associated with decreased ADL levels and increased mortality rates (6,20). Kim et al. reported that walking pattern parameters, such as step length, step width, walking angle, cadence, and double supporting period, in addition to walking speed, are associated with risks of gonalgia, urinary incontinence, and falls (8). Based on these findings, it may be important to provide walking guidance for the elderly through not only quantitative approaches, such as measuring the number of steps, but also qualitative approaches focusing on walking style represented by walking pattern parameter values.

In the present study, the effects of a walking support program were examined, with the aim of helping the elderly to improve their walking patterns and maintain appropriate walking styles. The program consisted of the following: information provision regarding walking and exercise; daily walking guidance based on the status of daily walking (including the daily number of steps and the activity levels) clarified through measurement using an accelerometer; and walking style guidance based on walking patterns clarified through recording and parameter measurement using a plate sensor.

Methods

1) Study systems

The present study was conducted by a study group for a research project entitled Techniques to Promote Effective Behavioral Changes in Consideration of Personal Characteristics, supported by a Grant-in-Aid for Scientific Research [Comprehensive Research Projects for the Prevention of Lifestyle-related Diseases Including Cardiovascular Diseases] from the Ministry of Health, Labour, and Welfare, using a program developed in cooperation between the Tokyo Metropolitan Institute of Gerontology and Kao Corporation Tokyo Research Laboratories. Assistance from the Health Promotion Division of the Bunkyo Ward government, Tokyo, was also obtained.

2) Participants

The appropriate number of male and female participants in each session (2 hours) was set at 40, and those meeting the following inclusion criteria were recruited through ward office bulletins: 1) those in their sixties or similar age groups who were aware of their insufficient exercise and able to walk independently, 2) those who were able to participate in the program on designated days, 3) those who were able to maintain appropriate lifestyles, 4) those who were able to submit a dated consent form with their seal or signature before the initiation of the program, and 5) those who were able to attach an accelerometer to their lower waist without problems. The exclusion criteria were as follows: 1) those considered to be inappropriate for participation by their primary doctors, 2) those in whom unfavorable symptoms, such as chest pain, shortness of breath, or arthralgia, may develop even with low- or moderate-intensity exercise, such as walking, 3) those considered to be inappropriate for participation by the person responsible, 4) those who were unable to participate in the program on designated days, and 5) those who were unable to maintain appropriate lifestyles. Based on these criteria, those who had submitted an informed consent form after the explanation of the study objective and content were included as participants.

3) Characteristics of the walking support program

(1) Study protocol (Fig. 1)

The study was conducted within the 4-month period between November 2011 and March 2012. At the initiation of the program, the following procedures were implemented while distributing the accelerometers: holding the first health seminar, performing body composition analysis, measuring walking pattern parameters, recording images, and providing walking style guidance based on the results of parameter measurement. Three weeks after the initiation of the program, daily walking guidance was provided based on the data obtained with the accelerometer, and its batteries were replaced with new ones. Seven weeks after initiation (on termination), the following procedures were implemented while collecting the accelerometers: holding the second health seminar, confirming changes in the participants' walking patterns based on the recorded images and obtained walking pattern parameter values, and providing walking style guidance. Furthermore, 10 weeks after termi-

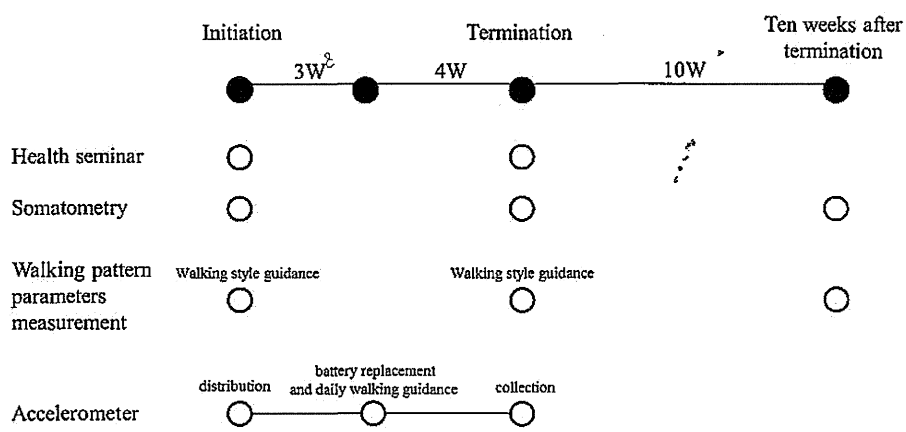

Fig. 1. Study Protocol for the Walking Support Program

nation, follow-up body composition analysis and walking pattern parameter measurement were performed.

(2) Daily walking guidance based on the status of daily walking

The participants were asked to keep the accelerometer (Lifecorder Plus; Suzuken Co., Ltd.) (9) attached to their lower waist at all times from rising to sleeping, excluding during some activities, such as bathing, to measure the number of steps, the activity levels, and durations of low-, moderate-, and high-intensity activities each day. During daily walking guidance, the status of walking was shown in a figure, with the number of steps and the activity levels as coordinates, to explain differences between actual and target values, and appropriate goals for individual participants were set. Target values were set based on the results of a study conducted by the Tokyo Metropolitan Institute of Gerontology in Nakanojo: the target daily numbers of steps for those under 70 and those aged 70 or over were 9,000 and 7,000, respectively, and the duration of moderate-intensity activity was 30 minutes/day (2). The activity levels recorded by the accelerometer at intervals of 4 seconds were scored on a 10-point scale (0 to 9 score) based on its own algorithm. Adopting the method used in a previous study (7), 1 to 3 were defined as low intensity, 4 to 6 as moderate, and 7 to 9 as high; levels 4 and higher corresponded to 3 METs or greater. The activity levels during each study period were shown as average values, estimated from daily average scores. Goals were carefully set so as to be achievable by individual participants without difficulty. For those whose actual number of steps was fewer than the target values, the duration of walking was increased by 5 to 10 minutes, and for those who had achieved such values, guidance was provided, explaining the relationship between walking speed and activity level, with a view to motivating them to further improve their walking speeds.

(3) Walking style guidance based on walking patterns

The participants were asked to freely walk along a 7-m course to measure their walking speed, step length and width, walking angle, cadence, and duration of the double supporting period, using a plate sensor (Walk Way; ANIMA Corporation) (4). Some walking pattern parameters measured in the present study are illustrated in Fig. 2. Although step length, step width, and walking angle were measured on both sides, only values on the left side were adopted for analysis. Images of participants' walking were displayed on a PC monitor, and their walking pattern parameter values

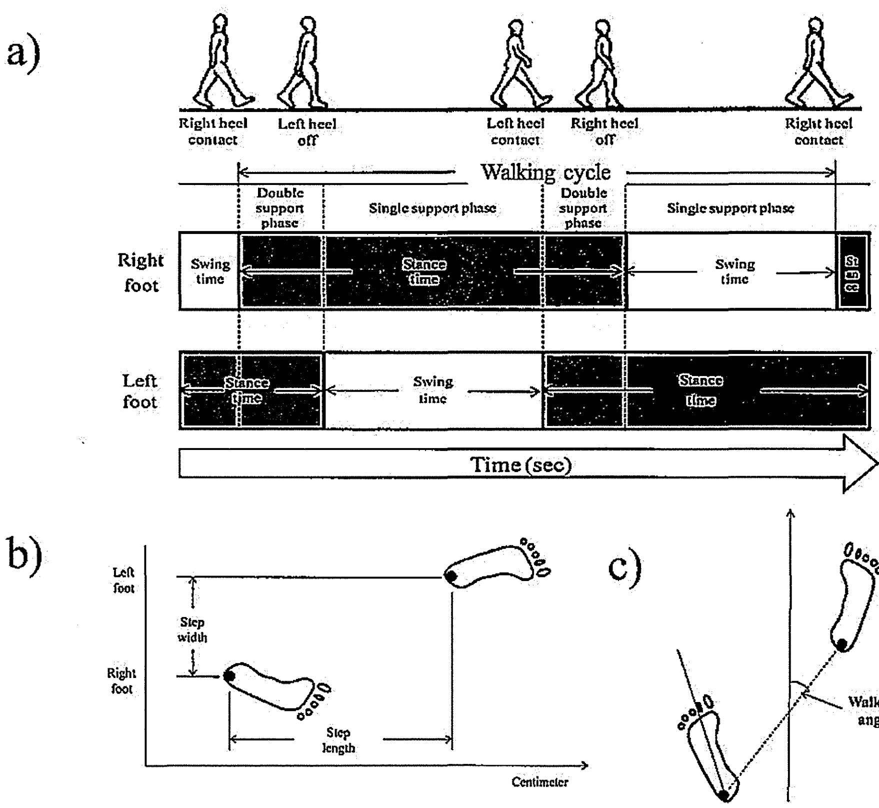

Fig. 2. Walking pattern parameters (Quoted from the literature 4)
a) Double-support phase
b) Step length, Step width
c) Walking angle

were clearly shown using radar charts. During this guidance, differences between such values and standards were explained to help them accurately recognize their own walking patterns. Standard values were determined based on data of free walking of males and females (13,19). In addition, "walking-based ages" of individual participants were also calculated using a regression equation (21), which was developed based on age-related changes in walking pattern parameter values, and presented. During the second walking style guidance, the effects were confirmed through clear comparisons of the results of the first and second sets of measurement.

(4) Body composition analysis

Height, weight, and body composition were measured at Weeks 0 and 17. The body composition being measured using a body composition analyzer (InBody-720; InBody Co., Ltd.) (1,24), height, weight, skeletal muscle mass, and body fat weight were clarified. This device uses an electrical current to directly measure the amount of extracellular and intracellular water in the body. The method is based on the principle that lean body mass contains virtually all water and conducts electrolytes in the body, providing a good electrical pathway, whereas fat or fat-containing tissue produces a poor electrical pathway. The device used in the present study uses 6 frequencies (1, 5, 50, 250, 500 and 1000 kHz) and produces 30 impedance values for 5 body segments. The values of skeletal muscle mass and body fat weight obtained from this device have been used in several studies (11,17).

(5) Health seminars

As a part of the program, 2 seminars were held by specialists to provide the latest health information, focusing on walking and daily activities. The first and second seminars were entitled <Tips for a Healthier and More Active Daily Life> and <Effective Walking Styles to Prevent Geriatric Syndrome>, respectively.

The main contents of the seminars were as follows:

- Changes in walking functions with age
- Physical characteristics of frailty in older adults
- Effects of walking on physical performance
- Methods for increasing daily activities

(6) Statistical analysis

Before and after daily walking guidance, paired t-tests were conducted for items, including the number of steps and the activity levels. Changes in the number of steps and the activity levels were examined by calculating Pearson's correlation coefficients. Initial and final body composition values were also analyzed using the paired t-test. Walking pattern parameter values were examined by one-way analysis of variance. For those showing a significant main effect, multiple comparisons were performed, adopting Bonferroni's method. Furthermore, changes in walking speed and walking pattern parameter values were examined by calculating Pearson's correlation coefficients. For statistics, statistical analysis software SPSS ver. 21 was used. In two-sided testing, a significant difference was set at 5% of the risk rate.

Results

1) Participants' attributes

Based on the inclusion and exclusion criteria, 44 were selected from those who applied to participate. Among them, 27 (69%) who completed the entire program, including activities on the final day, were studied. Their attributes were as follows: 2 males and 25 females, with a mean age of 67.56 ± 4.17, height of 154.89 ± 6.72 cm, and weight of 55.50 ± 21.09 kg (± standard deviation). Male attributes were as follows: age, 63 and 60; height, 168.00 and 174.00 cm; and weight, 73.30 and 78.00 kg. Female attributes were as follows: age, 68.04 ± 3.93; height, 153.60 ± 4.97; and weight, 53.88 ± 21.09 kg (± standard deviation).

2) Changes in daily walking (Table 1)

Table 1 shows changes in the number of steps, the activity levels, and durations of low-, moderate-, and high-intensity activities before and after daily walking guidance, revealing significant increases in the number of steps, the activity levels, and duration of moderate-intensity activity. The activity levels during each study period were shown as average values, estimated from daily average scores, with 1 to 3 defined as low intensity, 4 to 6 as moderate, and 7 to 9 as high; levels 4 and higher corresponded to 3 METs or greater. Changes in the number of steps also showed a significant correlation with the activity levels and duration of moderate-intensity activity.

3) Changes in walking pattern parameter values (Table 2)

Table 2 shows changes in walking speed, step length, step width, walking angle, cadence, and double supporting period at initiation, termination, and 10 weeks after termination. In one-way analysis of variance, main effect was observed in walking speed, step length, step width, and walking angle. Multiple comparisons revealed significant differences in walking speed between initiation and termination, those in step length between initiation and termination and between initiation and 10 weeks after termination, and those in walking angle between initiation and 10 weeks after termination. Furthermore, changes in walking speed were correlated with those in step length, cadence, and double supporting period.

4) Results of body composition

There were no significant differences in body fat mass, which changed from 14.50 ± 5.96 kg at initiation to 14.37 ± 5.67 kg at termination. In contrast, skeletal muscle mass significantly changed from 19.86 ± 4.13 kg at initiation to 20.14 ± 4.11 kg at termination (Table 3). Moreover, as shown in Fig. 3, changes in skeletal muscle mass were negatively correlated with changes in body fat mass ($r = -0.478$, $P = 0.012$).

Table 1. Changes in Values from the Activity Meter

	Before daily walking guidance	After daily walking guidance	Significant difference[1)]	Correlation coefficient with changes in number of steps[2)]
Daily number of steps (step/day)	9365±3000	10068±3251	*	–
The activity levels [3)]	2.94±0.67	3.08±0.70	*	0.631**
Duration of low-intensity activity (minutes/day)	58.56±20.67	57.67±18.73	NS	0.259
Duration of moderate-intensity activity (minutes/day)	30.45±18.16	35.87±20.00	*	0.894**
Duration of high-intensity activity (minutes/day)	3.37±4.82	3.89±5.67	NS	0.254

1) Conducting paired t-tests for the values obtained before and after daily walking guidance; *p<0.05
2) Examining the correlation of changes in the number of steps with those in other items before and after daily walking guidance by calculating Pearson's correlation coefficients; **p<0.01
3) The activity levels during each study period were shown as average values, estimated from daily average scores, with 1 to 3 defined as low intensity, 4 to 6 as moderate, and 7 to 9 as high; levels 4 and higher corresponded to 3 METs or greater.

Table 2. Changes in Walking Parameter Values

	Initiation	Termination	Ten weeks after termination	Significant difference[1)]	Correlation coefficient with changes in walking speed[3)]
Walking speed (km/h)	5.16±0.61	5.38±0.52 (*[2)] vs. Initiation)	5.39±0.63	*	–
Step length (cm)	69.36±6.83	71.60±6.51 (*[2)] vs. Initiation)	71.61±7.54 (*[2)] vs. Initiation)	**	0.876**
Step width (cm)	7.63±2.44	6.88±2.43	6.39±2.05	*	0.217
Walking angle (°)	6.34±2.09	5.60±2.09	5.22±1.76 (*[2)] vs. Initiation)	*	0.086
Cadence (steps/minute)	123.9±9.0	126.4±12.2	126.0±8.6	NS	0.841**
Double supporting period (%)	9.20±1.35	9.04±1.44	9.17±1.39	NS	−0.723**

1) Performing one-way analysis of variance; *p<0.05, **p<0.01
2) Performing multiple comparisons adopting Bonferroni's method; *p<0.05, **p<0.01
3) Examining the correlation of changes in the number of steps with those in other items on initiation and 10 weeks after termination by calculating Pearson's correlation coefficients; **p<0.01

Discussion

After daily walking guidance, the daily number of steps and the activity levels markedly improved. Among the walking pattern parameters, such effects were significant on walking speed, step length, step width, and walking angle. The changes observed in step length and walking angle 10 weeks after the termination of the program confirmed that the positive effects on these walking pattern parameters were maintained even during the follow-up period. Furthermore, an increase in skeletal muscle mass was observed on the final day.

Up to the present, the usefulness of approaches using