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Increases in Weight and Body Size Increase the Odds for Hypertension During 7 Years of Follow-up

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Abstract

Changes in BMI and body size were compared to incident hypertension in 24,550 men and 10,111 women followed prospectively as part of the National Runners' Health Study to test whether long-term weight change affects hypertension risk. Incident hypertension was reported by 2,143 men and 430 women during (mean $\pm$ s.d.) 7.8 ± 1.8 and 7.5 ± 2.0 years of follow-up, respectively. Despite being active, men's and women's BMI increased 1.15 ± 1.70 and 0.95 ± 1.89 kg/m², respectively, and their waist circumferences increased 2.97 ± 5.02 and 3.29 ± 6.67 cm, respectively. Compared to those whose BMI declined, those who gained 2.4 kg/m² had an odds ratio (95% confidence interval) of 1.68 (1.45, 1.94) for becoming hypertensive if male and 1.42 (1.05, 1.92) if female. Men whose waist circumference increased 6 cm had an odds ratio of 1.22 (1.01, 1.47) for becoming hypertensive compared to those whose waists decreased. In both sexes, 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 BMI. In the subset whose weights remained relatively unchanged during follow-up (± 0.4 kg/m²), each kg/m² increment in average BMI was associated with an odds ratio for becoming hypertensive of 1.19 (1.14, 1.24) in men and 1.11 (1.02, 1.20) in women. Thus, even among lean, physically active individuals: (i) weight gain increases hypertension risk; (ii) higher body weight increases the hypertension risk in a dose-dependent manner in the absence of any weight change; and (iii) there is no advantage carried forward to having been previously lean.

Introduction

Cross-sectional and prospective epidemiological studies have shown that blood pressure and hypertension are increased significantly with greater BMI and waist circumference (1–4). The relationships are observed in normal weight, overweight, and obese men and women (3–6). Clinical trials have also shown that weight loss lowers blood pressure (7,8); however, the results pertain primarily to overweight individuals followed for relatively short durations. Several prospective epidemiological studies relate hypertension to long-term changes in BMI or adiposity over time (9–15); however, most of these adjust for baseline BMI levels, which is statistically problematic and can produce statistical artifacts due to

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Disclosures

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measurement error (16). Moreover, most involve largely sedentary individuals, many of whom are moderately overweight or obese individuals. Runners and other vigorously active individuals may differ genetically from less active individuals (17,18), and it is not known whether their lower risk for hypertension (19) is due to persons who choose to be more physically active also having a lower risk for hypertension. In addition, there are few studies that document the health consequences of exercise recidivism and the associated weight gain among men and women who currently meet or exceed public health guidelines for physical activity.

The purpose of this study is to assess the relationship of long-term changes in adiposity as measured by BMI and body dimensions to the odds of developing hypertension among a vigorously active and generally lean population of men and women for whom the risk of developing hypertension may appear remote. We have previously demonstrated that runners gain weight in proportion to their reduction in distance run (20–22) which increases their risk for hypercholesterolemia (23). The present report assesses whether their weight gain also increases their risk for becoming hypertensive, and whether their risk for being hypertensive based on their current weight, is affected by a prior history of being lean.

Methods and Procedures

The survey instruments and baseline characteristics of the National Runners' Health Survey are described elsewhere (19–24). Briefly, a two-page questionnaire, distributed nationally at races and to subscribers of a popular running magazine (Runners' World, Emmaus, PA), solicited information on demographics, running history, weight history, smoking habits, prior history of heart attacks and cancer, and medications for blood pressure, thyroid conditions, high cholesterol, and diabetes. Recruitment took place between 1991 and 1994 (primarily 1993) and follow-up between 1999 and 2002. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research. The study protocol was approved by the University of California Committee for the Protection of Human Subjects, and all participants signed committee-approved informed consents.

BMI was calculated as self-reported weight in kilograms divided by the square of self-reported height in meters. Self-reported waist, hip, and chest circumferences were elicited by the question, "Please provide, to the best of your ability, your body circumference in inches" without further instruction. Bra cup sizes were coded on a 5-point scale: 1 (A cup), 2 (B cup), 3 (C cup), 4 (D cup), and 5 (E cup or larger). Elsewhere, we have reported the strong correlations between self-reported and clinically measured heights ($r = 0.96$) and weights ($r = 0.96$) (25), and for self-reported running distances vs. self-reported BMIs and waist circumferences in longitudinal analyses (20–22). Self-reported body circumferences are somewhat less precise, as indicated by their correlations with reported circumferences on a second questionnaire for waist ($r = 0.84$), hip ($r = 0.79$), and chest ($r = 0.93$) and with their clinical measurements (waist $r = 0.68$; hip $r = 0.63$; chest $r = 0.77$) (25). We report these body dimensions as further support for the association between increasing adiposity and the risk for hypertension. Imprecision in these self-reported values will attenuate the significance of their association with hypertension, and the resulting estimates will

underestimate the magnitude of the true relationships (26). Biases in self-reported weight might also affect estimated risk (see caveats in the Discussion). Physical activity was reported as distance run each week. Although other leisure-time physical activities were not recorded for this cohort, data from runners recruited after 1998 (when the survey question was introduced) show that running represents ($\pm$ s.d.) $91.5 \pm 19.1\%$ and $85.2 \pm 24.0\%$ of all vigorously intense activity in men and women, respectively, and $73.5 \pm 23.7\%$ and $69.4 \pm 25.7\%$ of their total reported leisure-time physical activity. Self-reported distance run has been found to be highly reliable (test–retest correlations of $r = 0.89$ (25)). Furthermore, 80% of the 54,956 participants of the National Runners' Health Study provided follow-up information or were known deceased.

The analyses are restricted to 24,550 male and 10,111 female participants who were nonhypertensive at baseline. Participants reported whether a physician had told them they had high blood pressure since their baseline questionnaire, and whether they took medications for high blood pressure at baseline and follow-up. Incident hypertension is defined as physician diagnosis or starting medications for high blood pressure subsequent to their baseline questionnaire. Using repeated surveys and confirmed diagnosis from medical records, self-reported hypertensions have been demonstrated by others as being generally reliable (27) and are reported by other major cohort studies (28–30). Self-reported physician diagnosis of hypertension has also been shown to be a strong predictor of myocardial infarction and stroke in the Nurses' Health Study (29).

Statistics

Changes in BMI and body dimensions between baseline and follow-up are denoted as Δ BMI and Δ body dimensions, and the average of the baseline and the follow-up BMI or body dimensions are denoted $\text{BMI}_{\text{average}}$ and $\text{body dimensions}_{\text{average}}$, respectively. Analysis of variance was used to assess the relationship of the continuous variables to categories of weight loss. We employed logistic regression analyses to test whether Δ BMI or Δ body dimensions were related to the incidence of hypertension, where Δ BMI and Δ dimensions were included as continuous (tables) or categorical variables (figures). The 0.8 kg/m^2 increment for Δ BMI categories was chosen by inspection to provide five equal-width intervals of similar sample size. Stable weight was defined as $\pm 0.4 \text{ kg/m}^2$ in BMI (one-half the increment used in our study of Δ BMI) or 0 cm change in waist circumference. Logistic regression was also used to test whether the follow-up adiposity was related to the incidence of hypertension when adjusted for baseline adiposity, and simultaneously whether baseline adiposity was related to incident hypertension when adjusted for the follow-up adiposity. All results (except the descriptive results of Table 1) include adjustment for the average age during follow-up (age and age²), follow-up duration, and the average weekly intakes of alcohol, meat, fish, and fruit at baseline and follow-up.

Results

There were 24,550 nonsmoking men and 10,111 nonsmoking women with complete data on height and body weight at baseline and at the end of follow-up, who were not strict vegetarians and who did not report baseline hypertensive or diabetic medication use. At

baseline, these men and women were generally middle aged (male and female mean $\pm$ s.d.: 44.1 ± 10.2 and 38.3 ± 9.8 years, respectively), college-educated (16.5 ± 2.4 and 15.9 ± 2.3 years of education), and lean (BMIs of 23.8 ± 2.5 and 21.2 ± 2.3 kg/m²), who reported eating 2.8 ± 2.7 and 1.7 ± 2.0 serving of meat, 1.5 ± 1.4 and 1.2 ± 1.3 servings of fish, and 11.0 ± 8.7 and 11.5 ± 8.0 pieces of fruit per week, respectively, and who drank in moderation (79.6 ± 111.2 and 47.8 ± 71.8 ml alcohol per week, respectively). The men ran an average of 37.9 ± 22.8 and the women an average of 36.0 ± 21.6 km/week.

Table 1 displays the sample characteristics by BMI. The data show that the proportion of men and women who became hypertensive during follow-up was twice as high for those who gained 2.4 kg/m² compared to those who lost weight. In addition, men and women who experienced greater increases in BMI were significantly younger and less active than others, and tended to show greater decreases in running distance between baseline and end of follow-up. At the end of the follow-up, 86% of the women and 55% of the men fell within the definition of healthy weight (BMI ≤ 25 kg/m²), and 85% of the women and 90% of the men fell within the recommended levels for waist circumference (women <88 cm, men <102 cm). The correlation between BMI at baseline and follow-up was $r = 0.84$ in men and $r = 0.80$ in women.

Weight-stable runners

Included in the sample were 5,576 men and 2,826 women whose weight remained within ± 0.4 kg/m² of their baseline BMI ($\sim \pm 3$ pounds for a 6-foot man). There were 382 incident hypertensions among these men and 101 among the women. These data were used to calculate the odds ratio for hypertension as a function of BMI_{average} in the absence of any major weight change. Per kg/m² increase in BMI_{average}, the odds ratio (95% confidence interval) for becoming hypertensive was 1.19 (1.14, 1.24) in men ($P < 0.0001$) and 1.11 (1.02, 1.20) in women ($P = 0.02$). Figure 1 shows that, relative to BMI_{average} <20 kg/m², the men's odds for becoming hypertensive increased progressively with higher BMI_{average} (significant above 22.5 kg/m²) such that the odds were 7.7-fold greater for BMI_{average} 27.5 kg/m² compared to the leanest men. Women with BMI_{average} 27.5 kg/m² had over 5.3-fold greater odds of becoming hypertensive compared to those with BMI_{average} <20 . Adjustment for physical activity during follow-up had little effect on the odds ratios.

There were also 5,974 men and 1,709 women who reported no change in their waist circumferences, of whom 433 and 52 reported becoming hypertensive, respectively. The men's odds ratio for becoming hypertensive was 1.07 (1.05, 1.09) per cm increment in waist circumference_{average} ($P < 0.0001$). Compared to waist circumference_{average} 78 cm, there was a progressive increase in the men's odds for hypertension with higher circumferences, which achieved statistical significance for categories 82 cm (86 cm when adjusted for physical activity, Figure 2). The odds ratio for women becoming hypertensive was not significantly related to their waist circumferences.

All runners

Table 2 shows that the odds ratios for becoming hypertensive increased significantly in relation to BMI and all body dimensions. The odds ratios for BMI and waist

circumference in men, chest circumference in both sexes, and bra cup size in women remained significant when adjusted for BMI_{average} or body dimensions_{average}. Except for waist circumference in men and bra cup size in women, adjustment for physical activity (km/week) had little effect on the odds ratios for becoming hypertensive. Both greater BMI_{average} and body dimensions_{average} increased the odds for becoming hypertensive when adjusted for BMI and body dimensions.

Figure 3 displays the odds ratios for becoming hypertensive in relation to BMI and waist circumference. As suggested by Table 2, adjustment for the BMI_{average} or waist circumference_{average} substantially diminished the odds ratios. Nevertheless, men with BMI 2.4 kg/m² or waist circumference 6 cm were at significantly greater odds for becoming hypertensive than those who reduced their BMI or waist circumference when adjusted for the averages. Women who increased their BMI 2.4 kg/m² were also at significantly greater odds for becoming hypertensive relative to those who lost weight. Adjustment for physical activity during follow-up had little effect (results not shown).

Other analyses (not shown) suggest that the odds ratio for BMI vs. incident hypertension was significantly greater ($P = 0.002$) in younger men 50 years (odds ratio 1.28 (1.23, 1.32) per kg/m², $P < 0.0001$) than older men (1.18 (1.13, 1.22), per kg/m², $P < 0.0001$), even when adjusted for average BMI (younger vs. older men: 1.14 (1.10, 1.18) vs. 1.08 (1.04, 1.12), $P = 0.01$ for difference). In contrast, among women the odds ratio for BMI vs. incident hypertension was marginally greater ($P = 0.08$) after the age of 50 years (odds ratio 1.23 (1.14, 1.33) per kg/m², $P < 0.0001$) than before (1.10 (1.05, 1.16), per kg/m², $P < 0.0001$), even when adjusted for average BMI (older vs. younger women: 1.15 (1.26, 1.05) vs. 0.99 (0.93, 1.05), $P = 0.02$ for difference).

Table 3 displays the odds ratio for the body dimension and bra cup size when adjusted for BMI and BMI_{average}. Average waist and chest circumference in men and chest circumference in women showed statistically independent odds ratios for hypertension when adjusted. Changes in other body dimension became nonsignificant when adjusted for BMI and BMI_{average}. In contrast, the odds for developing hypertension remained significantly related to BMI when adjusted for body dimensions (results not shown).

Table 4 presents the odds ratios for becoming hypertensive relative to the baseline and the end of follow-up BMI and body dimensions. The odds ratios are adjusted for physical activity (those without adjustment for physical activity were essentially the same and are not shown). In these analyses, the significance of the end of follow-up value is adjusted for the baseline, and conversely, the baseline significance level is adjusted for the end of follow-up. In every case, the odds for becoming hypertensive were more strongly related to BMI and body dimension at the end of follow-up than at baseline. For most variables, the baseline levels were not significantly related to the odds for becoming hypertensive when adjusted for the follow-up (exceptions were men's waist and chest circumference). The increased odds for becoming hypertensive with greater chest circumference at follow-up in women remained significant when adjusted for BMI; however, the associations between other body circumferences and bra size at the end of follow-up appear attributable to their association with BMI.

Discussion

This paper demonstrates that weight gain in men and women increases the odds for becoming hypertensive. The odds for incident hypertension with weight gain were greater in younger than older men and greater in older than younger women. Adjustment for physical activity had little effect on the increase in odds due to weight gain. Moreover, the end-of-follow-up body weights and sizes determined the odds for becoming hypertensive regardless of the baseline values. This suggests there was little advantage carried forward to having been previously lean. It also suggests that greater weight causes hypertension rather than the converse, which would affect both the baseline and follow-up weights if true. A second important finding is that the maintenance of a leaner body weight, in the absence of any weight change, lowered the odds for becoming hypertensive. We are unaware of any other prospective study that restricted their analyses to weight-stable individuals. These results supplement our traditional prospective analyses of baseline BMI and baseline waist circumference as predictors of incident hypertension during follow-up (24).

Table 1 showed that BMI was concordantly related to higher BMI_{average}, which motivated our use of statistical adjustment to assess their independent effects. Our analyses adjusted BMI for BMI_{average} rather than BMI_{baseline} (29–34) because measurement error associated with BMI will be uncorrelated with the measurement error associated with BMI_{average} (16). Table 2 shows that this adjustment substantially reduced the odds ratios for BMI. In contrast, adjusting for baseline levels produces minimal affect or increased the odds ratios relating men's and women's incident hypertension to BMI (odds ratios (95% confidence intervals): 1.20 (1.17, 1.23) and 1.10 (1.06, 1.15), respectively), waist circumference (1.05 (1.04, 1.06), 1.04 (1.02, 1.05), respectively), chest circumference (1.04 (1.03, 1.05), 1.06 (1.04, 1.08), respectively), women's incident hypertension to hip circumference (1.03 (1.02, 1.05)), and bra cup size (1.29 (1.11, 1.50)). The difference between these values and those of Table 2 are consistent with the conclusion by Cain et al. that adjusting for the baseline values can produce misleading results (16).

Even when adjusted for BMI_{average} or body dimensions_{average}, BMI and circumferences of the waist and chest were significantly related to increases in the men's odds for developing hypertension. Smaller samples meant less statistical power to detect significant associations in women; yet changes in two indices of upper body fat, chest circumference, and bra cup size were significantly associated with increased odds for becoming hypertensive. Figure 3 shows that BMI 2.4 kg/m² and waist circumference 6 cm significantly increased the men's odds for hypertension even when adjusted for average levels and physical activity during follow-up. In women, BMI 2.4 kg/m² also increased the odds for developing hypertension when adjusted.

Additional analyses were performed to assess whether the associations between incident hypertension with body dimensions were statistically independent of the BMI. With the exception of chest circumference in women, the associations of body circumferences were not statistically independent of BMI, suggesting that changes in body circumferences and bra cup size were primarily reflective of overall weight change. Similarly, except for women's chest circumferences, body circumferences and bra cup size at the end of follow-

up were also primarily reflective of BMI at follow-up. Thus, changes in self-reported circumferences and bra cup sizes provide additional confirmation of the association based on self-reported weight, but do not necessarily specify regional effects on the risk for hypertension. The importance of regional adiposity in affecting the hypertension risk is supported, however, by the significant odds ratios of waist circumference_{average} and chest circumference_{average} when adjusted for BMI (Table 3).

One interpretation of Table 4 is that the effect of BMI on blood pressure depends primarily on current BMI and that the follow-up measure most strongly reflects the BMI level that triggered hypertension. Table 1 shows that 74% of men and 73% of women were heavier at the end of follow-up than at baseline. Thus, for most individuals, baseline and the end of follow-up BMI are not simply two independent estimates of on-study weight but rather represent the starting and ending values of a progressive increase in BMI with age.

Caveats

The principal limitations of these analyses are the select nature of the sample and the reliance on self-reported body weight, body circumferences, and diagnosis of hypertension. Biases in reporting body weight should not affect the analysis of hypertension vs. weight change if the bias remains constant at both baseline and follow-up, but might somewhat inflate the odds ratios for BMI if there is a tendency within the same individuals to underreport weight at higher values. The bias of under-reporting body weight in our sample is probably less than in other epidemiological cohort studies because 72% of the men and 94% of the women were at or below-ideal weight (BMI ≤ 25) at baseline, and only 2% of the men and 0.6% of the women were overweight (BMI > 30). Self-reported body weights and hypertension have been presented in other major cohort studies (35–37) and produced similar results in men and women. Although self-reported body dimensions are subject to greater error than are height and weight used in the calculation of BMI (see Methods and Procedures), the consistency of the associations reported here in their relation to hypertension support their use. There are a substantial number of papers suggesting that waist circumference and possibly other body size measurements are at least in part independently related to the risk for hypertension (4,38–40). Although our sample was restricted to physically active men and women, adjustment for their principal physical activity has little effect on the findings. The minimal effect of the adjustment is consistent with the observation that the relationship of body weight to the risks for becoming hypertensive is similar in low, moderate, and highly physically active men (41). However, the men and women studied in this report are generally leaner than those reported in other studies (9–15).

Our analyses are also limited in their focus on physician-diagnosed hypertension rather than blood pressure as a continuous outcome. Observational data clearly demonstrate that the risks for ischemic heart disease and stroke fatality increase progressively from as low as 115mmHg and systolic 75mm diastolic through higher values, with a doubling of the risks for both with each 10mmHg in diastolic and 20mmHg systolic (42). Hypertensions diagnosed between 1991 and 2002 are also unlikely to include prehypertension (systolic 120–139mmHg, diastolic 80–89mmHg) as promoted by the Seventh Report of the Joint

National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (42).

In summary, these results further support the need to prevent weight gain and exercise recidivism even among ostensibly healthy weight men and women.

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Figure 1.

Increasing odds ratios of incident hypertension by average BMI in 5,576 men and 2,826 women whose BMI remained stable (± 0.4 kg/m²) during follow-up. Results adjusted to the mean age, follow-up duration, and reported intakes of meat, fish, fruit, and alcohol. Additional adjustment for physical activity (km/week) where indicated. Brackets define 95% confidence intervals. Significance levels are coded †P < 0.01; ‡P < 0.001; §P < 0.0001.

Figure 2.

Increasing odds ratios of incident hypertension by average waist circumference in 5,974 men and 1,709 women whose waist circumferences did not change during follow-up. Results adjusted to the mean age, follow-up duration, and reported intakes of meat, fish, fruit, and alcohol. Additional adjustment for physical activity (km/week) and BMI_{average} where indicated. Brackets define 95% confidence intervals. Significance levels are coded *P < 0.05; †P < 0.01; §P < 0.0001.

Figure 3.

Relationships of the odds ratio of incident hypertension by BMI and waist circumference during follow-up in 24,550 men and 10,111 women. Results adjusted to the mean age, follow-up duration, reported intakes of meat, fish, fruit, and alcohol. Additional adjustment for average BMI or waist circumference at baseline and follow-up where indicated. Brackets define 95% confidence intervals. Significance levels are coded * $P < 0.05$; † $P < 0.01$; ‡ $P < 0.001$; § $P < 0.0001$.

Table 1

sample characteristics by change in BMI

	BMI (kg/m ²)						
	<0	0.0–0.79	0.80–1.59	1.60–2.39	2.40	Significance	
Males							
Sample (N)	6,326	5,774	5,138	3,143	4,169		
Hypertension incidence % (N)	7.51 (475)	6.53 (377)	8.04 (413)	9.04 (284)	14.25 (594)	<0.0001	
Follow-up duration (years)	7.39 ± 1.86	7.51 ± 1.81	7.79 ± 1.71	8.11 ± 1.66	8.59 ± 1.63	<0.0001	
Age _{average} (years)	50.19 ± 10.61	49.08 ± 10.16	47.73 ± 9.57	46.94 ± 9.19	44.31 ± 9.45	<0.0001	
BMI _{average} (kg/m ²)	23.72 ± 2.59	23.58 ± 2.27	24.18 ± 2.35	24.87 ± 2.40	26.41 ± 3.03	<0.0001	
BMI _{baseline} (kg/m ²)	23.99 ± 2.67	23.33 ± 2.26	23.57 ± 2.34	23.88 ± 2.40	24.46 ± 2.84	<0.0001	
BMI follow-up (kg/m ²)	23.45 ± 2.58	23.83 ± 2.28	24.78 ± 2.36	25.85 ± 2.41	28.36 ± 3.42	<0.0001	
BMI (kg/m ²)	−0.55 ± 0.87	0.50 ± 0.20	1.21 ± 0.23	1.98 ± 0.22	3.90 ± 1.65		
Physical activity _{average} (km/wk)	33.92 ± 21.11	34.30 ± 20.89	32.56 ± 19.65	29.99 ± 18.32	26.22 ± 16.64	<0.0001	
Physical activity (km/wk)	−5.02 ± 20.34	−9.21 ± 19.35	−12.21 ± 19.46	−16.28 ± 20.02	−23.25 ± 22.02	<0.0001	
Females							
Sample (N)	3,379	2,185	1,987	1,104	1,456		
Hypertension incidence % (N)	3.70 (125)	3.20 (70)	3.47 (69)	4.35 (48)	8.10 (118)	<0.0001	
Follow-up duration (years)	7.30 ± 2.05	7.27 ± 2.11	7.64 ± 1.95	7.80 ± 2.00	8.22 ± 1.84	<0.0001	
Age _{average} (years)	42.23 ± 10.32	42.70 ± 9.77	41.58 ± 9.50	41.70 ± 9.33	41.55 ± 9.15	0.0008	
BMI _{average} (kg/m ²)	21.13 ± 2.24	20.83 ± 1.94	21.34 ± 2.01	22.19 ± 2.27	24.40 ± 3.16	<0.0001	
BMI _{baseline} (kg/m ²)	21.43 ± 2.35	20.60 ± 1.93	20.77 ± 2.01	21.23 ± 2.27	22.28 ± 2.80	<0.0001	
BMI follow-up (kg/m ²)	20.84 ± 2.20	21.06 ± 1.95	21.90 ± 2.02	23.15 ± 2.27	26.55 ± 3.94	<0.0001	
BMI (kg/m ²)	−0.59 ± 0.79	0.46 ± 0.20	1.13 ± 0.24	1.92 ± 0.24	4.24 ± 2.15		
Physical activity _{average} (km/wk)	33.08 ± 20.08	33.56 ± 19.11	31.28 ± 18.87	28.12 ± 17.32	22.65 ± 16.06	<0.0001	
Physical activity (km/wk)	−6.90 ± 21.13	−8.39 ± 19.36	−11.04 ± 20.13	−13.43 ± 19.42	−18.87 ± 20.38	<0.0001	

Means ± s.d. except for incidence, which is the percent (count). Significance refers to the relationship of the variable to BMI over a continuum of reported values.

Table 2

Odds ratios (95% confidence intervals) from logistic regression analyses of incident hypertension vs. changes in BMI and regional adiposity

Physical activity adjustment:	Unadjusted for average BMI or body circumference ^d		Adjusted for average BMI or body circumference ^d	
	None	Adjusted	None	Adjusted
Males				
BMI (kg/m ²)	1.23 [†] (1.20, 1.26)	1.20 [†] (1.17, 1.23)	1.11 [†] (1.08, 1.14)	1.09 [†] (1.06, 1.13)
BMI _{average} (kg/m ²)			1.16 [†] (1.14, 1.18)	1.16 [†] (1.14, 1.18)
Waist circumference (cm)	1.05 [†] (1.04, 1.05)	1.04 [†] (1.03, 1.05)	1.01 ^{**} (1.00, 1.02)	1.01 (0.99, 1.03)
Waist circumference _{average} (cm)			1.06 [†] (1.06, 1.07)	1.06 [†] (1.05, 1.07)
Chest (cm)	1.03 [†] (1.02, 1.04)	1.03 [†] (1.02, 1.04)	1.02 ^{***} (1.01, 1.03)	1.01 ^{**} (1.00, 1.02)
Chest circumference _{average} (cm)			1.05 [†] (1.05, 1.06)	1.05 [†] (1.04, 1.06)
Females				
BMI (kg/m ²)	1.13 [†] (1.09, 1.18)	1.12 [†] (1.07, 1.17)	1.03 (0.99, 1.08)	1.03 (0.98, 1.08)
BMI _{average} (kg/m ²)			1.14 [†] (1.10, 1.18)	1.14 [†] (1.10, 1.18)
Waist circumference (cm)	1.03 [†] (1.02, 1.05)	1.03 ^{***} (1.01, 1.04)	1.01 (1.00, 1.03)	1.01 (1.00, 1.03)
Waist circumference _{average} (cm)			1.05 [†] (1.03, 1.06)	1.05 [†] (1.03, 1.06)
Chest (cm)	1.03 ^{***} (1.01, 1.05)	1.03 ^{***} (1.01, 1.04)	1.02 (1.00, 1.03)	1.01 (1.00, 1.03)
Chest circumference _{average} (cm)			1.04 [†] (1.02, 1.06)	1.04 [†] (1.02, 1.06)
BMI (kg/m ²)	1.06 [†] (1.04, 1.08)	1.05 [†] (1.03, 1.07)	1.04 ^{***} (1.02, 1.06)	1.04 ^{***} (1.02, 1.06)
BMI _{average} (kg/m ²)			1.05 [†] (1.03, 1.07)	1.05 [†] (1.03, 1.07)

Physical activity adjustment:	Unadjusted for average BMI or body circumference ^a		Adjusted for average BMI or body circumference ^a	
	None	Adjusted	None	Adjusted
Bra cup (size)	1.22 ^{**} (1.05, 1.42)	1.19 [*] (1.03, 1.39)	1.17 [*] (1.01, 1.36)	1.15 (0.99, 1.33)
Bra cup _{average} (size)			1.22 ^{***} (1.08, 1.37)	1.20 ^{**} (1.07, 1.36)

^a Adjusted for mean age, follow-up duration, and reported intakes of meat, fish, fruit, and alcohol. Additional adjustment for physical activity (km/week) where indicated.

Significance levels for odds ratios are coded:

- * P < 0.05,
- ** P < 0.01,
- *** P < 0.001,
- [†] P < 0.0001.

Table 3

Odds ratios (95% confidence intervals) from logistic regression analyses of incident hypertension vs. regional adiposity

Physical activity adjustment:	Unadjusted for average body circumference ^a		Adjusted for average body circumference	
	None	Adjusted	None	Adjusted
Males				
Waist circumference (cm)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	0.99 (0.98, 1.01)
Waist circumference _{average} (cm)			1.02** (1.01, 1.03)	1.02** (1.01, 1.03)
Chest (cm)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)
Chest circumference _{average} (cm)			1.01* (1.00, 1.02)	1.01* (1.00, 1.02)
Females				
Waist circumference (cm)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.01 (0.99, 1.02)	1.01 (0.99, 1.02)
Waist circumference _{average} (cm)			1.01 (0.99, 1.04)	1.02 (1.00, 1.04)
Hip circumference (cm)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)
Hip circumference _{average} (cm)			0.99 (0.97, 1.01)	0.99 (0.97, 1.02)
Chest (cm)	1.03* (1.00, 1.05)	1.03* (1.00, 1.05)	1.03* (1.00, 1.05)	1.02* (1.00, 1.05)
Chest circumference _{average} (cm)			1.01 (0.99, 1.04)	1.01 (0.99, 1.04)
Bra cup (size)	1.08 (0.92, 1.26)	1.08 (0.92, 1.26)	1.08 (0.92, 1.26)	1.07 (0.91, 1.25)
Bra cup _{average} (size)			1.04 (0.91, 1.18)	1.04 (0.91, 1.19)

^a Adjusted for mean age, follow-up duration, and reported intakes of meat, fish, fruit, and alcohol. Additional adjustment for physical activity (km/week) where indicated.

Significance levels for odds ratios are coded:

* P < 0.05,

** P < 0.001

Table 4

Odds ratios (95% confidence intervals) from logistic regression analyses of incident hypertension vs. baseline and follow-up BMI and regional adiposity

Independent variable:	Unadjusted for BMI		Adjusted for BMI	
	Baseline	Follow-up	Baseline	Follow-up
Males				
BMI (kg/m ²)		1.18 [†] (1.15, 1.21)		
Waist circumference (cm)	0.99 (0.95, 1.02)	1.04 [†] (1.03, 1.05)	1.02 [*] (1.00, 1.03)	1.00 (0.99, 1.02)
Chest circumference (cm)	1.02 ^{***} (1.01, 1.03)	1.04 [†] (1.03, 1.05)	1.01 (0.99, 1.02)	1.01 (1.00, 1.02)
Females				
BMI (kg/m ²)	1.01 [*] (1.00, 1.02)			
Waist circumference (cm)		1.09 [†] (1.05, 1.14)		
Hip circumference (cm)	1.04 (0.98, 1.10)	1.04 [†] (1.02, 1.05)	1.00 (0.98, 1.03)	1.01 (1.00, 1.03)
Chest circumference (cm)	1.01 (0.99, 1.03)	1.03 [†] (1.02, 1.05)	0.99 (0.97, 1.01)	1.00 (0.98, 1.02)
Bra cup (sizes)	1.00 (0.98, 1.03)	1.06 [†] (1.04, 1.08)	0.98 (0.96, 1.01)	1.03 [*] (1.01, 1.06)
	0.99 (0.97, 1.02)	1.26 ^{**} (1.09, 1.47)	0.95 (0.80, 1.14)	1.09 (0.93, 1.29)
	0.95 (0.81, 1.13)			

^aOdds ratios adjusted for mean age, follow-up duration, and reported intakes of meat, fish, fruit, and alcohol.

Significance levels for odds ratios are coded:

- * P < 0.05,
- ** P < 0.01,
- *** P < 0.001,
- [†] P < 0.0001.