Decreasing Association Between Body Mass Index and Blood Pressure Over Time

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Background: Our purpose was to assess blood pressure (BP) and its relationship with body mass index (BMI) over a 15-year interval in the Seychelles, a rapidly developing country in the African region.
Methods: Two independent cross-sectional examination surveys were conducted in 1989 (n = 1081) and 2004 (n = 1255) using representative samples of the population age 25–64 years.
Results: Between 1989 and 2004, mean BP (mm Hg) decreased slightly (from 133/87 to 131/86 in men and from 127/82 to 124/81 in women), with little change in the age-standardized prevalence of high BP (BP ≥140/90 or current treatment; from 45% to 44% in men and from 34% to 36% in women). During this same time period, there were marked increases in awareness (from 42% to 64%), treatment (22% to 59%), and control (3% to 20%) among participants with high BP. The prevalence of overweight (BMI ≥25 kg/m^2) increased from 39% to 60%. Furthermore, the linear relationship between BMI and BP was markedly weaker in 2004 than in 1989, irrespective of antihypertensive treatment and age, and among both lean and overweight participants. Among untreated persons, a BMI increment of 1 kg/m^2 was associated with an elevation of 2.0/1.5 mm Hg of systolic/diastolic BP in 1989 but only 1.3/1.0 mm Hg in 2004.
Conclusions: The association between BMI and BP has decreased over time. Further study is needed to understand the reasons for the decline in this association, and what the implications are in the context of the obesity epidemic.

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High blood pressure (BP) is a leading cause of the global burden of disease.[1] In 2000, 26% of the adult worldwide population was affected by hypertension and 29% were projected to have this condition by 2025.[2] Two-thirds of the hypertension-attributable burden of disease occurs in the developing world.[3] Data from the past 2 decades suggest that the prevalence of hypertension has decreased in most developed countries,[4,5] but has increased in several developing countries.[5]

Whereas increasing proportions of hypertensive persons are being treated, the rates of hypertension control remain generally poor and vary greatly across regions.[4,5] Recent estimates suggest that among all hypertensive persons in North America, 44% were treated and 23% controlled (BP <140/90 mm Hg), while in 6 European countries, 27% were treated and only 8% controlled.[6] The few available population-based studies in developing countries suggest even lower control rates.[7,8]

The prevalence of hypertension, and of several other conditions (including diabetes), is considered to be linked to the worldwide epidemic of obesity.[9] The strong association between BP and body weight has been well documented in various populations.[8,10–13] However, unlike the prevalence of diabetes, which has increased over time in parallel with obesity,[14] mean BP and the prevalence of hypertension have decreased in many developed countries.[4,15] Part of the decrease in mean BP over time may relate to larger proportions of hypertensive persons under treatment. Nevertheless, a study assessing BP trends in the 38 populations of the WHO MONICA project between the mid 1980s and the mid 1990s showed a decrease in mean BP in the entire distribution of BP readings, suggesting that much of the decrease was not attributable to antihypertensive medication.[16] The causes of this apparent BP decline over time in these populations remain largely unexplained.

One possible explanation for the diverging trends in the frequency of obesity and hypertension is that the relationship between body mass index (BMI) and BP might have changed over time. In this paper, we assess trends over time in mean BP, prevalence, awareness, treatment and control of high BP, and explore the relationship between BP and BMI in the Seychelles, a rapidly developing country in the African region. Our analyses are based on 2 independent surveys conducted in 1989 and in 2004 using almost identical sampling and measurement methods.

METHODS

The Republic of Seychelles is located in the Indian Ocean, 1800 km off the coast of Kenya (hence in the African Region). The large majority of the population is of African descent and its ethnic composition has remained stable over the past several decades. The national gross domestic product per capita rose, in real terms, from US$ 2927 in 1980 to US$

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5239 in 2004. Cardiovascular diseases currently account for nearly 40% of all deaths, cancer for 15%, and AIDS/HIV for less than 1%. A high prevalence of cardiovascular risk factors such as high blood pressure, hypercholesterolemia, diabetes, smoking, and obesity has been documented in the adult population both in 1989 and 2004.[17,18]

Health care has been delivered for several decades through a national health service with no direct fees to users, and at least 1 drug was available for most types of antihypertensive medications in 1989 and 2004. Since 1991, a national campaign has been launched to raise awareness of cardiovascular risk factors.

The Seychelles Heart Studies

Independent population-based examination surveys of cardiovascular risk factors were conducted in 1989[17] and in 2004.[18] For both surveys, the sampling frame consisted of a random sex- and age-stratified sample of the population aged 25–64 years. Eligible individuals were selected from a database derived from population censuses carried out in 1987 and 2002 and regularly updated by civil status authorities. Eligible persons included all those listed in the census data after exclusion of those dead (14), living abroad (24), or unknown by district administrative authorities (32) out of 1635 persons in 2004. The samples were drawn from the entire population in 2004, and from the population of the main island (90% of the total population) in 1989. Quality control procedures in both 1989 and 2004 surveys included calibration of scales by National Bureau of Standards and checks using known weights, training of survey officers to measurement techniques, and pilot administration of the questionnaires.

Measures

Both surveys followed similar methodologic procedures.[17,18] BP was measured with a mercury sphygmomanometer. Our analyses are based on the average of the last 2 of 3 readings taken at intervals greater than 2 minutes after the participants had been resting for at least 30 minutes, to limit overestimation of BP related to anxiety associated with the first BP readings.[19] Cuff size (normal or large) was adjusted to arm circumference. High BP was defined as systolic/diastolic BP $\geq$ 140/90 mm Hg or current antihypertensive treatment. Weight was measured using calibrated scales at 0.2 kg precision (Seca, Hamburg, Germany). Height was measured with fixed stadiometers at 0.5 cm precision (Seca). BMI was calculated as weight divided by squared height (kg/m^2). External factors that may affect BP were similar in both surveys (eg, temperature is constant at around 28°C–30°C throughout the year, and use of stimulants or nonessential medications has remained uncommon). Participants were fasting, and were also requested not to smoke, drink, or eat before completion of all measurements.

In both surveys, trained officers administered a structured questionnaire. Awareness of hypertension was determined by asking participants if they had been told by a medical doctor that they had elevated BP or hypertension. Current antihypertensive drug treatment was determined by asking participants if they were currently taking a pharmacological treatment for hypertension. Participants were asked to bring along their medications. Alcohol consumption was assessed by beverage-specific quantity/frequency questions; on this basis, mean total ethanol intake was calculated. In this report, we considered categories of average alcohol intake of 0, 1–59, and $\geq$60 mL ethanol per day. Participants' occupation (as a proxy variable for socioeconomic status) was assessed in 3 categories based on current or most recent job: laborer and other nonqualified; intermediate; and qualified nonmanual. Both surveys were approved by the Ministry of Health following technical and ethical reviews and conducted under the auspices of this Ministry. Subjects were free to participate and gave informed consent (oral consent in 1989 and written consent in 2004).

Statistical Analysis

For both surveys, all estimates (except for Lowess analysis) were weighted for age and sex to the WHO standard world population.[20] Differences in overall estimates (eg, change between 1989 and 2004) were tested with the χ^2 test for categorical variables and the t test for continuous variables, standardized for age. The shape of the relationship between BMI and systolic/diastolic BP was assessed using the Lowess method,[21] a scatter-plot smoothing technique based on robust locally weighted regression. In view of the linear relationship, we used linear regression models to fit the relationship between BMI and BP. Regression models were adjusted for selected confounding variables (age, sex, alcohol intake, occupation, and antihypertensive treatment). Models were first fit separately for both surveys, including or excluding treated participants. We further evaluated whether the relationship between BP and BMI changed between 1989 and 2004 in a model that included participants of both surveys, introducing an interaction term (product term: BMI*survey) and adjusted for potentially confounding variables. All regression models were weighted to account for the sex- and age-stratified sampling frame. We performed analyses with Stata 9.0 (StataCorp, College Station, TX).

RESULTS

In 1989, 1081 participants aged 25–64 years took part in the survey (participation rate 86%); in 2004 there were 1255 participants (80%). The distribution of age-adjusted mean systolic and diastolic BP, BMI, daily alcohol and tobacco consumption, and occupation categories are presented on Table 1.

The prevalence of high BP increased across age categories and tended to be higher in men than in women (Table 2). The prevalence of high BP did not change substantially between 1989 and 2004 in any of the age and sex groups. Among subjects with high BP, awareness, treatment, and control of the condition were markedly higher in 2004 than in 1989, especially in women. Between 1989 and 2004, the prevalence of subjects aged 25–64 with BP $\geq$160/100 mm Hg decreased from 19% to 13% among men and from 12% to 9% among women.

Between 1989 and 2004, mean systolic and diastolic BP tended to decrease among both men and women (Fig. 1). During the same period, mean BMI rose markedly in all age

TABLE 1. Blood Pressure, Body Mass Index, and Selected Participants' Characteristics,* by Sex and Survey Year

	Men		Women	
	1989 (n = 513)	2004 (n = 568)	1989 (n = 568)	2004 (n = 687)
Systolic BP (mm Hg)	132.7 ± 0.9	131.1 ± 0.7	127.3 ± 1.0	124.4 ± 0.7
Diastolic BP (mm Hg)	87.1 ± 0.7	85.5 ± 0.5	82.5 ± 0.6	81.3 ± 0.4
BMI (kg/m^2)	23.3 ± 0.2	25.5 ± 0.2	25.9 ± 0.3	28.3 ± 0.3
Ethanol intake (ml/d)	71.4 ± 4.4	40.1 ± 3.4	8.6 ± 1.2	3.7 ± 0.5
Number of cigarettes per day	6.5 ± 0.4	3.2 ± 0.3	0.7 ± 0.1	0.3 ± 0.1
Occupation (%)				
Laborers	36	26	50	45
Intermediate qualification	54	58	36	36
Qualified nonmanual workers	10	16	13	18

All estimates are adjusted for age to the WHO standard world population.
*Mean ± standard error, unless otherwise indicated.

groups and in both sexes. Meanwhile, the prevalence of treated high BP increased markedly, especially among older age groups. Overall, 7% of all men and 11% of all women aged 25–64 were treated in 1989, respectively 21% and 26% in 2004.

Figure 2 illustrates the crude relationship between BMI and systolic and diastolic BP among untreated men and women for each survey. The relation between BMI and both systolic and diastolic BP was approximately linear, both in 1989 and 2004. However, the slope was clearly less steep in 2004 than in 1989. The same patterns of trends were found in analyses conducted separately in participants aged 25–44 or 45–64 or when including subjects treated for hypertension (data not shown, available upon request).

Table 3 shows the linear regression coefficients between BMI and BP by sex and survey year. Adjustment for

TABLE 2. Prevalence of High Blood Pressure (BP) Among All Participants and Rates of Awareness, Treatment, and Control Among Participants With High BP

				Among Participants With High BP					
		High BP (%)		Aware (%)		Treated (%)		Controlled (%)	
Age Group (yrs)	No. in 1989, 2004	1989	2004	1989	2004	1989	2004	1989	2004
Men									
25–34	105, 126	26	23	33	31	4	24	0	10
35–44	127, 134	46	39	33	48	21	38	2	13
45–54	145, 158	55	56	38	64	14	58	1	12
55–64	136, 150	68	73	40	65	18	63	3	11
Women									
25–34	123, 149	8	10	40	60	20	60	0	40
35–44	143, 176	34	30	43	66	22	60	2	34
45–54	145, 181	48	52	54	77	38	72	9	24
55–64	157, 181	66	70	52	84	34	83	5	31
Standardized (age 25–64 yrs)									
Men	513, 568	45	44	36	55	15	49	2	12
Women	568, 687	34	36	49	75	31	72	5	30
Both sexes	1081, 1255	40	40	42	64	22	59	3	20
Standardized (age 35–64 yrs)									
Men		54	53	37	60	18	54	2	12
Women		47	47	50	77	32	73	5	29
Both sexes		51	50	43	68	24	63	4	20

High BP is defined as systolic/diastolic BP ≥140/90 mm Hg or current antihypertensive treatment.

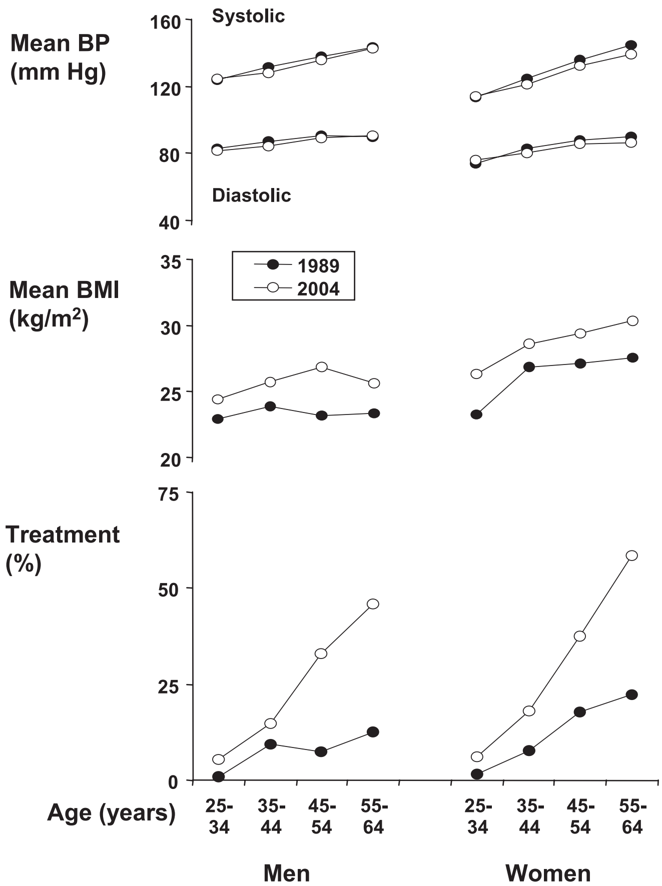

FIGURE 1. Mean systolic/diastolic blood pressure, mean body mass index and prevalence of treated high BP among all participants in 1989 and in 2004.

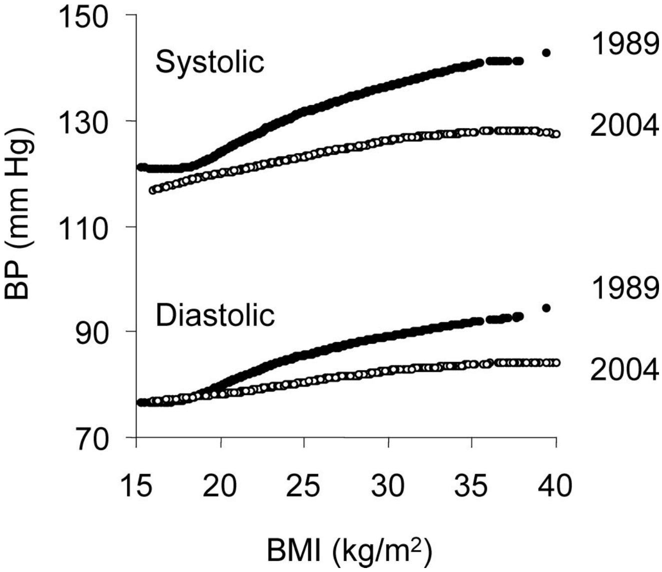

FIGURE 2. Smoothed curves relating systolic and diastolic blood pressure and body mass index in untreated subjects in 1989 and in 2004.

potentially confounding variables such as age, alcohol intake and occupation (all associated with systolic and diastolic BP; results not shown) tended to weaken the relationship between BP and BMI, particularly in women. Since smoking status was not associated with BP and is not an important risk factor for hypertension, we did not include it in the models. The association between BP and BMI was virtually unchanged whether participants under antihypertensive treatment were included (and treatment factored in the model as an indicator variable) or excluded from the analyses. Overall, the magnitude of the regression coefficient of BMI on BP decreased substantially and consistently between 1989 and 2004, irrespective of sex and antihypertensive treatment.

Table 4 shows the difference between the slopes of the linear regression of BMI on BP as observed in 2004 and 1989. This difference corresponds to the interaction between survey year and BMI in multivariate models relating BMI to BP, adjusting for the potential confounding variables indicated in Table 3. For example, the interaction coefficient of −0.71 (systolic BP, "all", untreated) means that systolic BP increased by 0.71 mm Hg less in 2004 than in 1989 for each unit of BMI (1 kg/m^2). The analysis by subgroups shows that the interaction coefficient between survey year and BMI was of similar magnitude, irrespective of sex, age, or BMI category.

The equations corresponding to the multivariate models among untreated persons are: systolic BP = 1.98*BMI + 12.94*year [1989: 0; 2004: 1] + 0.57*age + 8.07*sex [0: women; 1: men] + 1.96* daily ethanol intake of 1–59 mL [no: 0; yes: 1] + 4.86* daily ethanol intake of ≥60 mL [no: 0; yes: 1] − 0.44* intermediate qualification occupation [no: 0; yes: 1] − 3.98* highly qualified occupation [no: 0; yes: 1] − 0.71*BMI*year + 68.85 and diastolic BP = 1.46*BMI + 9.45* year + 0.26*age + 5.40*sex + 1.27* daily ethanol intake of 1–59 mL + 4.30* daily ethanol intake of ≥60 mL − 0.36* intermediate qualification occupation − 2.18* highly qualified occupation − 0.50*BMI*year + 45.98. It follows from the models that the slope of the regression of BMI on systolic BP was 1.98 mm Hg per unit of BMI in 1989 (ie, 1.98−0.71*0) and 1.27 in 2004 (ie, 1.98−0.71*1). Therefore, the increase in systolic BP related to a BMI increase from 25 to 35 kg/m^2 was 19.8 mm Hg in 1989, but only 12.7 mm Hg in 2004. Similarly, the predicted increase in diastolic BP associated with a 10-kg/m^2 BMI increase was 14.6 mm Hg in 1989, but only 9.6 mm Hg in 2004.

DISCUSSION

While mean BMI increased sharply in the Seychelles between 1989 and 2004, mean BP and the prevalence of high BP remained essentially unchanged at the population level. A major finding was the secular decline in the direct relationship between BMI and BP, which was not explained by the increasing proportion of hypertensive persons under treatment in the interval.

This study has some limitations. First, BP was assessed on a single visit, which is likely to result in an overestimation.[22] Second, medication was self-reported, which could

TABLE 3. Univariate and Multivariate Association Between Blood Pressure and Body Mass Index in 1989 and in 2004

	1989				2004			
	All		Not Treated*		All		Not Treated*	
	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)
Systolic blood pressure								
Men								
Unadjusted	1.59	(1.08–2.09)	1.49	(0.93–2.06)	0.94	(0.65–1.22)	0.90	(0.57–1.22)
Adjusted†	1.47	(1.00–1.94)	1.57	(1.07–2.07)	0.72	(0.43–1.00)	0.91	(0.58–1.23)
Women								
Unadjusted	1.61	(1.27–1.94)	1.45	(1.10–1.81)	0.86	(0.66–1.06)	0.55	(0.36–0.75)
Adjusted†	0.94	(0.63–1.26)	1.09	(0.77–1.41)	0.28	(0.11–0.46)	0.38	(0.18–0.57)
All								
Unadjusted	1.36	(1.08–1.63)	1.19	(0.89–1.49)	0.69	(0.52–0.86)	0.49	(0.31–0.67)
Adjusted†	1.10	(0.84–1.36)	1.23	(0.96–1.50)	0.45	(0.31–0.60)	0.58	(0.42–0.74)
Diastolic blood pressure								
Men								
Unadjusted	1.26	(0.93–1.58)	1.24	(0.88–1.61)	0.62	(0.42–0.82)	0.63	(0.41–0.86)
Adjusted†	1.20	(0.87–1.52)	1.31	(0.97–1.66)	0.48	(0.28–0.68)	0.64	(0.42–0.87)
Women								
Unadjusted	1.09	(0.89–1.29)	1.00	(0.79–1.20)	0.55	(0.42–0.67)	0.41	(0.27–0.55)
Adjusted†	0.74	(0.56–0.91)	0.81	(0.63–1.00)	0.29	(0.16–0.41)	0.36	(0.21–0.50)
All								
Unadjusted	0.95	(0.77–1.12)	0.86	(0.68–1.05)	0.45	(0.34–0.56)	0.38	(0.26–0.50)
Adjusted†	0.88	(0.72–1.04)	0.96	(0.79–1.13)	0.35	(0.25–0.45)	0.45	(0.33–0.57)

β indicates linear regression coefficient of body mass index on blood pressure (mm Hg/kg/m^2).
*Not treated: models do not include persons under antihypertensive treatment.
†Adjusted: covariates include age, sex, alcohol intake, occupation and antihypertensive treatment.

lead to some misclassification. This bias was reduced since most participants brought their medications along. These limitations are unlikely to explain the decreasing relationship between BMI and BP over time since the same procedures and devices for BP measurement were used in 1989 and 2004. Third, since there were more very obese persons in

TABLE 4. Difference in the Relation Between Blood Pressure (mm Hg) and Body Mass Index (kg/m^2) Between 1989 and 2004 by Subgroups of Selected Variables

	No. Participants		Systolic Blood Pressure				Diastolic Blood Pressure			
			All		Not Treated		All		Not Treated	
	All	Not Treated	Change in β	(95% CI)	Change in β	(95% CI)	Change in β	(95% CI)	Change in β	(95% CI)
Sex										
Men	1081	892	−0.72	(−1.25 to −0.18)	−0.65	(−1.24 to −0.06)	−0.66	(−1.02 to −0.29)	−0.63	(−1.03 to −0.23)
Women	1255	966	−0.77	(−1.11 to −0.43)	−0.77	(−1.13 to −0.40)	−0.57	(−0.78 to −0.36)	−0.52	(−0.76 to −0.29)
Age (yrs)										
25–44	1083	989	−0.63	(−0.97 to −0.29)	−0.52	(−0.86 to −0.18)	−0.43	(−0.68 to −0.19)	−0.33	(−0.58 to −0.08)
45–64	1253	869	−0.75	(−1.21 to −0.30)	−0.83	(−1.35 to −0.31)	−0.66	(−0.92 to −0.40)	−0.73	(−1.03 to −0.43)
BMI (kg/m^2)										
<25	1086	983	−0.98	(−1.92 to −0.05)	−1.18	(−2.13 to −0.22)	−0.86	(−1.45 to −0.26)	−0.95	(−1.58 to −0.33)
≥25	1250	875	−0.67	(−1.24 to −0.09)	−0.71	(−1.36 to −0.05)	−0.40	(−0.76 to −0.04)	−0.35	(−0.77 to 0.07)
All	2336	1858	−0.74	(−1.02 to −0.47)	−0.71	(−1.02 to −0.41)	−0.56	(−0.74 to −0.38)	−0.50	(−0.70 to −0.30)

Results are from multivariate regression models that are adjusted for age, sex, survey year, alcohol intake, occupation and antihypertensive treatment.
Change in β indicates difference in the regression coefficients between 2004 and 1989 (ie, interaction between survey year and BMI).

2004 than in 1989, the use of a large cuff instead of a very large cuff (in relation to arm circumference) might have led to some overestimation of BP in 2004 as compared with 1989. However, this bias is probably minimal as the prevalence of extreme obesity was low and the change in the BMI-BP relationship was of similar magnitude among both lean and overweight persons. Furthermore, overestimation of BP due to higher prevalence of extreme obesity in 2004 than in 1989 would tend to underestimate the secular decrease in the BMI-BP relationship.

Some residual confounding by socioeconomic status cannot be ruled out since the 3-category indicator is rather imprecise. However, years of education would not be a better indicator in our study as the number of years of obligatory education has increased dramatically over the past few decades in the Seychelles and education years tends to be a proxy of a person's age in this population. More generally, the issue of capturing socioeconomic status in developing countries is a difficult and still unsolved problem.[23]

The strengths of the study include its base in independent population-based surveys with high participation rates, and use of same procedures in both surveys. The prevalence of high BP in Seychelles (40% at age 25–64 and 50% at age 35–64) is higher than in North America (28% at age 35–64) and Europe (44% at age 35–64)[6] and much higher than in several African countries.[24] As in Western Europe and in the US,[4,16,25] the prevalence of high BP in Seychelles has not increased over the past 15 years (and even decreased in terms of mean BP), while it has increased in several developing countries.[24] Control of high BP has largely improved in the Seychelles in the past 15 years, and control indicators (eg, proportions of hypertensive persons aware of their condition, under medication and with BP controlled) are now more similar to those in high-income than low-income countries.[26]

The direct and linear relationship between BP and BMI has persisted over time, albeit at a weaker level. Such a relationship has been consistently found in the literature, including in developing countries,[8,12] both in observational studies[27] and controlled trials.[28] In our study, BP was also associated directly with alcohol intake and inversely with occupational qualification (as a proxy for socioeconomic status), findings that are consistent with other reports,[29,30] with no secular trends observed in this study.

A question arising from our findings is whether the association between BMI and BP observed at the first survey is stronger than expected or, instead, is the association observed at the second survey weaker than expected? The magnitude of the relationship in the first survey seems typical of findings in population surveys, eg, the INTERSALT study[31] and other single-site community surveys.[32,33] However, these surveys (mostly among non-Africans) were performed in the late 1970s to 1990s and new studies should re-examine the strength of the BMI-BP relationship in these same populations more recently (assuming population weight gain over time). In a recent study in the African Diaspora,[34] the BMI-BP relationship varied greatly among populations (eg, from 0.27 mm Hg/kg/m^2 in male African Americans to 1.73 mm Hg/kg/m^2 in male Ghanaians) and, generally, decreased across populations in Africa, the Caribbean islands, and America, respectively, and along an increasing gradient of prevalence of overweight.

The secular and substantial weakening of the relationship between BMI and BP independent of antihypertensive treatment may be due to other factors, for example, period-specific bias in the measurement of BMI or BP (or both), or changes in the environment of the population.

In terms of systematic biases in the measurement of BP or BMI, selection bias could result from the exclusion of participants under antihypertensive treatment, since these participants are more likely to be obese and the prevalence of treatment for hypertension has increased between 1989 and 2004. If true, this would have led to a decrease in the strength of the relationship between BMI and BP mainly among older subjects, whose proportion under treatment increased most during the period of observation. However, the decreasing relationship between BMI and BP was similar within all treatment subgroups and age groups (the younger age category being largely untreated in both surveys). This suggests that the observed secular trend in the BMI-BP relationship is not explained by the increasing treatment prevalence over time.

The role of a regression-dilution bias—which relates to imprecision in exposure measurement—could be suggested. Such a bias is unlikely to account for the difference in the BMI-BP relation, as BMI was measured using same methods in both surveys and, in addition, this measurement is fairly precise and reliable. Variability in the measurement of BP was minimized by taking the average of the last 2 of 3 BP readings.

Alternative explanations for the decreasing BMI-BP relationship over time include secular changes in other factors associated with both BMI and BP that are not adjusted for in our analyses. Examples might be dietary characteristics (other than alcohol), socioeconomic factors (other than occupation), and physical exercise. Trends in the intake of salt, fruits and vegetables, or levels of physical exercise cannot be directly observed in our surveys, but a recent study in Seychelles showed fairly low salt intake.[35] However, these well known determinants of BP and BMI are not known to affect the BMI-BP relationship, neither in this study (by testing corresponding interactions) nor in the literature. An effect of accommodation of individuals to BP measurement could possibly account for some of the difference in BP levels between 2004 and 1989. However, this factor is likely to be minimal as BP measurement was already performed routinely for all persons attending primary health care in 1989. Furthermore, such an effect would be unlikely to affect the BMI-BP relationship differentially in 2004 and in 1989. Another argument against an accommodation effect is the finding of a similar change in the BMI-BP relationship between 1989 and 2004 in old or treated persons (submitted to frequent BP measurement) and in young or nontreated persons (less likely to undergo frequent BP measurement).

We assumed that adiposity is causally related to BP and we used BMI as a proxy for adiposity. However, BMI is also directly related to lean mass and therefore we cannot distinguish which component (increased adiposity or increased lean mass) is more important in determining the level of BP.[36] Alternative indicators of adiposity (eg, waist circumference, direct assessment of visceral and subcutaneous body fat) could help provide insight in mechanisms underlying the changing BMI-BP relationship. For example, since BP tends to relate more strongly to waist circumference than to BMI,[37] changes in the adiposity distribution of individuals over time might underlie differences in the BMI-BP relationship. At a closer physiological level, changes in adiposity patterns of individuals over time (particularly in relation to abdominal fat) could affect BP levels through adipocyte-released hormones, cytokines and other factors produced and/or modulated by abdominal/visceral fat.

To the best of our knowledge, this study is the first to directly investigate the relationship between BMI and BP over time in the same population. However, there is other, indirect evidence for a weakening of the association between BMI and BP. For example, an 18% decrease in the prevalence of high BP was reported in the United States among obese persons between 1960–1962 and 1999–2000.[38] In the MONICA populations, a decline in BP was observed despite an increase in BMI.[16,39] From a broader perspective, the relative risk of mortality associated with obesity was lower in American health surveys in the 2000s than in the 1970s and the authors suggested that the reduced impact of obesity on mortality could relate to improvements in public health and medical care over time.[40]

Our study suggests that there is a factor (or a set of factors), distinct from treatment of high BP, that attenuated the effect of overweight on high BP over time and, perhaps, on the incidence of cardiovascular events. These findings should be replicated in other populations and in longitudinal studies. If confirmed, a decreasing association between BMI and BP over time could imply that the impact of the overweight epidemic on cardiovascular disease might be less important than predicted. This decreased relationship could also help to explain the current favorable trends in cardiovascular disease (declining incidence) observed in many countries despite the increasing prevalence of obesity.

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