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Understanding the role of mediating risk factors and proxy effects in the association between socio-economic status and untreated hypertension

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Abstract

The association between socio-economic status (SES) and untreated hypertension varies according to a country's level of development and racial/ethnic group. We sought to confirm this variation in women from China and the United States (US) as well as to investigate the impact of SES on several mediating risk factors. We also investigate the extent to which SES explains racial/ethnic differences in untreated hypertension in the US. We used cross-sectional data from 1814 non-pregnant women in China (China Health and Nutrition Survey (CHNS), 1997) and 3266 non-pregnant women in the United States (National Health and Nutrition Examination Survey (NHANES III), 1988–1994) respectively. A variety of statistical modelling techniques was used to predict untreated hypertension as a function of several mediating factors and to simulate the impact of changes in SES. The age-adjusted prevalence of untreated hypertension was significantly higher ($p<0.01$) for low-income White and Black women compared to Mexican American or Chinese women. Untreated hypertension was not significantly associated with income or education in Mexican Americans or women in China. Obesity and light physical activity had the largest mediating effect on the association between SES and untreated hypertension for all racial/ethnic groups. However, this effect was not as strong as the proxy effect of income and education. SES did not completely explain racial/ethnic differences in hypertension in the US. While SES was more strongly associated with hypertension in Blacks than Whites, Blacks were still 1.97 (95% CI 1.47–2.64) times more likely to have untreated hypertension than Whites after adjusting for SES differences. The association between SES and untreated hypertension varied by country and racial/ethnic group. An important explanation for this variation was the differential effect of SES on mediating risk factors. SES disparities between Whites and Blacks in the US partly explain differences in the prevalence of untreated hypertension between these racial/ethnic groups.

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Keywords: Socio-economic status; Untreated hypertension; Racial/ethnic group; Mediating risk factors; China; USA

Introduction

There is an inverse association between socio-economic status (SES) and hypertension in high-income countries, whereas in many lower income countries, the relationship is positive (Colhoun, Hemingway, & Poulter, 1998). The association between SES and hypertension is also known to vary with racial/ethnic group (Okosun, Liao, Rotimi, Choi, & Cooper, 2000). In China, for example, SES is low compared to the US and while the prevalence of untreated hypertension is also lower, it is increasing. In the US, non-Hispanic Blacks (Blacks) are over-represented in low SES groups, and hypertension-related morbidity and mortality is considerably higher than for non-Hispanic Whites

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(Whites) (Burt et al., 1995). Mexican Americans, on the other hand, tend to have hypertension rates similar to Whites in spite of having lower SES (Franco et al., 1985). Scholars have focused on numerous intermediate or mediating risk factors through which SES could influence hypertension, and it is possible that variations in hypertension by country and racial/ethnic group are partly due to the differential effect of SES on these factors (Williams & Collins, 1995).

SES does not affect hypertension directly. Rather, SES influences 'health behaviors' such as diet, alcohol consumption, smoking, physical activity and other risk factors which in turn affect hypertension (Mosley & Chen, 1984). These associations are not always straightforward, and changes in SES may create offsetting risks. For example, the prevalence of obesity is lower in women with high SES in developed countries, but alcohol consumption has been found to be higher (Stamler et al., 1992). Both obesity and excessive alcohol consumption are risk factors for hypertension; therefore, the lower prevalence of hypertension in high SES women, due to their lower obesity prevalence, may be offset by their higher levels of alcohol consumption (Marmot et al., 1994). Another complication is that SES variables in statistical models are actually a proxy for unmeasured, unmeasurable or poorly measured mediating risk factors. Using our own analysis as an example, we have drawn a pathway model to illustrate this (Fig. 1). Pathway 1a highlights the role of the four mediating risk factors (obesity, physical activity, alcohol consumption and smoking status) studied in this analysis. Pathway 1b shows that SES also operates through other mediating risk factors, which in our case are unmeasured and include sodium, potassium and psychosocial stressors. SES may also operate through factors we are unable to measure at an epidemiological level, such as the presence or absence of coping mechanisms—John Henryism (Adams, Aubert, & Clark, 1999) or other complex social mechanisms (Kaufman & Cooper, 1999). Pathway 1b also captures variation in the risk factors we have measured but may have measured poorly. Body mass index (BMI), for example, is justified as a measure of obesity because it is strongly correlated with body fat and has been associated with cardiovascular disease risk factors in numerous studies. However, body fatness may not be the only reason why obese individuals have higher blood pressure. Pathway 1b then is the SES proxy effect. While not considered in this study, the diagnosis, treatment and control of hypertension may also be influenced by SES (pathway 2) (Sorel, 1992).

This paper aims to confirm variation in the association between SES and untreated hypertension in women from China and the United States (US) as well as to investigate the impact of SES on several mediating risk factors. We also investigate the extent to which SES explains racial/ethnic differences in untreated hypertension in the US.

Methods

Participants

Participants were non-pregnant women, aged 30–65 years old, from the CHNS and the NHANES III. The CHNS is an ongoing longitudinal survey conducted jointly by the Chinese Academy of Preventive Medicine (CAPM) and the University of North Carolina at Chapel Hill. The survey used multistage random cluster sampling to select participants from 3800 households in eight provinces of China that vary considerably in geography, stage of economic development and health status. Further details of the survey design have been published elsewhere (Popkin, Paeratakul, Keyou, & Fengying, 1995). We used 1997 cross-sectional data in this analysis from 1814 non-pregnant women with

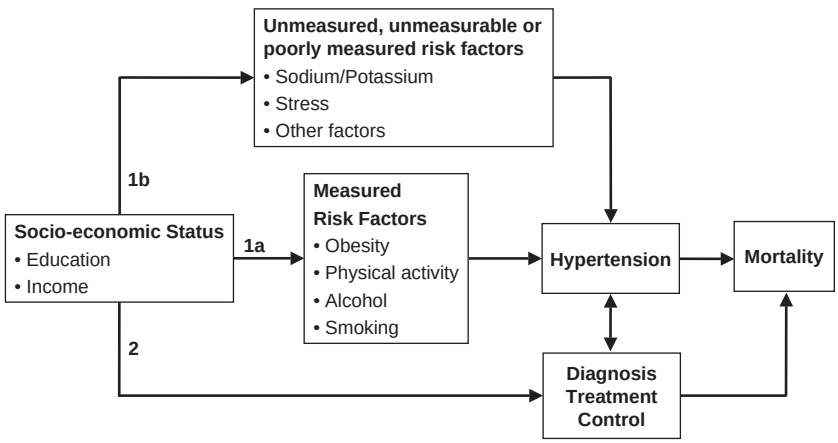

Fig. 1. Pathways through which SES may influence hypertension.

recorded blood pressure data. Similar data from 3266 women in NHANES III were used. The NHANES III survey, conducted by the National Center for Health Statistics (NCHS) in two phases between 1988 and 1994, used a multi-stage sampling design to provide national estimates of the health and nutritional status of the United States' non-institutionalized population. Black and Mexican American populations were over-sampled. Details of this survey have been published by other authors and can be found at the NCHS website (National Center for Health Statistics, 2000). The data were not weighted and are therefore not nationally representative. Our primary interest was the association between SES and untreated hypertension and not in the prevalence of hypertension per se.

Measures

Our outcome variable was untreated hypertension, hereafter called hypertension. Standard procedures for blood pressure measurement were used in both surveys. Three measurements of blood pressure were taken on the right arm of each participant, who were seated prior to the measurement. Standard mercury sphygmomanometers were used with appropriate cuff sizes. Systolic blood pressure was measured at the first appearance of a pulse sound (korotkoff phase 1) and diastolic blood pressure at the disappearance of the pulse sound (korotkoff phase 5). We used the average of three measurements. Hypertension was defined as a systolic blood pressure $\geqslant 140$ mmHg and/or a diastolic blood pressure $\geqslant 90$ mmHg. We excluded those using antihypertension medication ($n = 216$ Whites, 268 Blacks, 100 Mexican Americans and 47 Chinese) because the association between SES and hypertension is likely to be different between treated and untreated individuals. For example, those on medication may have modified their risk factor profile by increasing physical activity or losing weight since being diagnosed.

To measure SES we used simple main effect dummy variables for household income, over the year prior to the survey. In the US sample, income was categorized into ethnic specific tertiles. We also used years of education, which were divided into low (<12 years), medium (12 years) and high (>12 years) categories, and focused on the combined effect of low income and low education (low SES) and high income and high education (high SES). We investigated other interactions (i.e., low income, high education) but they were not informative beyond emphasizing the fact that income and education generally have a synergistic association with hypertension. We used a similar definition in the CHNS, but education was divided into low (<3 years), medium (3–7 years) and high (>7 years) of education.

The mediating risk factors we included were obesity prevalence, prevalence of light physical activity, alcohol consumption and smoking status. Obesity was defined as BMI $\geqslant 30\,kg/m^2$ in the US ethnic groups and $\geqslant 25\,kg/m^2$ in China. This lower cut-off has been recommended by the International Obesity Task Force for defining obesity in Asian populations (International Diabetes Institute, 2000). Height was measured in centimeters without shoes and weight was measured in kilograms without shoes and in light clothing.

Physical activity was defined based on leisure activity in the United States and on work activity in China. The NHANES III survey included questions on whether or not subjects participated in nine common physical activities in the past month, including walking, cycling, swimming, aerobics, dance, and gardening. We created a variable that added all activities for each individual and then collapsed it into two levels: light activity (0 or 1 activities in the past month) and moderate to heavy activity (2 or more activities per month). Participants in China were classified into a dichotomous physical activity variable separating light and moderately active work activity from heavy work activity (i.e., a teacher was considered to have light physical activity whereas a dancer was heavily active). Previous research has found this to be a good measure of physical activity and to be related to weight change (Bell, Ge, & Popkin, 2001). In both surveys, frequent alcohol consumption was defined as consuming alcohol one or more times per week and smokers were those who were current smokers at the time of the survey.

Statistical analysis

The associations between SES and hypertension were similar for men and women, but we only present results for women because we found, like others, that the associations were stronger in women than men (Colhoun et al., 1998).

To measure the association between SES and the mediating risk factors for hypertension, we calculated the age-adjusted prevalence of each risk factor within each racial/ethnic group, separately for Chinese women, across three categories of income and education. We then used logistic regression to predict hypertension as a function of these factors. Obesity (yes/no), physical activity (light vs. moderate to heavy), frequency of alcohol consumption (once/week vs. less than once/week), smoking status (current smoker (yes/no)) and age, which was continuously defined within the range 30–65 years of age, as independent variables. We also included income (medium and high vs. low), education (medium and high vs. low) to estimate the proxy effect of SES.

To further explore the mediating effect of obesity, physical activity, alcohol consumption and smoking (pathway 1a), we simulated the change in the average predicted prevalence of hypertension that would occur if

all women had a prevalence of each of these risk factors that was typical of those with low SES. We then repeated the process, this time giving women from each racial/ethnic group a risk factor profile that was typical of those with high SES. To examine the proxy effect of SES (pathway 1b), we held the measured risk factors constant and simulated the impact of assigning all women in each racial/ethnic group to either low SES or high SES.

To investigate the extent to which SES explains racial/ethnic differences in hypertension in the US, we pooled the data from White, Black and Mexican American women and redefined the income categories for the whole sample. We then used logistic regression to determine if SES modified the relationship between hypertension and race, comparing a saturated model, that included interaction terms between race and the other main effects, with a reduced model that excluded the race–SES interaction terms. We ran the main effects model, with and without SES, to test for confounding. Finally, using the main effects model that included income and education, we predicted what a change in income and education would do to the prevalence of hypertension for each ethnic group. Significance levels of $p<0.05$ were used, unless otherwise stated, and all analyses were performed using Stata statistical software, version 7 (Statacorp, College Station, TX).

Results

The age-adjusted prevalence of hypertension varied significantly with income for White and Black women and with education for Black women, but not for Mexican Americans and women in China (Table 1). However, risk factor prevalence varied significantly with income and education for all groups, including China. For each US-ethnic group, the prevalence of obesity, light physical activity and smoking was significantly lower among women with high-income, compared to those with low income. Frequent alcohol consumption was common among high-income White women and low-income Blacks. Similar associations were observed with education. In China, obesity and light physical activity were higher with high income and high education. Few Chinese women consumed alcohol one or more times per week or smoked, although these

Table 1
Age-adjusted prevalence of, and measured risk factors for, untreated hypertension by income and education for non-Hispanic White, non-Hispanic Black, Mexican American and Chinese women

	United States									China		
	Non-Hispanic White			Non-Hispanic Black			Mexican American			Chinese		
Income-thirds[a]	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
Sample, *n*, and percentage (%)	448 (32)	531 (38)	417 (30)	291 (30)	365 (38)	314 (32)	301 (33)	358 (38)	241 (27)	619 (34)	606 (33)	589 (33)
Risk level												
Hypertension (%)	11.0	6.5*	5.2†	19.7	12.4	12.0*	10.3	8.5	7.3	11.8	10.8	13.0
BMI $\geqslant 25\,kg/m^2$ (%)	54.0	52.1	44.4†	73.5	71.6	65.8*	72.2	74.7	65.9	15.4	18.4	27.1†
BMI $\geqslant 30\,kg/m^2$ (%)	27.9	23.4	19.0†	45.4	40.4	37.4*	42.8	32.8†	33.3*	1.2	2.1	1.9
Light physical activity[b] (%)	72.4	63.6†	52.5†	82.4	78.5	70.7†	89.6	82.0†	72.1†	27.5	39.9†	61.0†
Alcohol consumption[c] (%)	23.2	26.6	39.9†	23.3	22.1	15.1†	13.6	11.1	19.5	2.9	6.6†	5.0
Smoker[d] (%)	38.0	22.9†	17.3†	39.7	37.9	22.2†	22.2	13.2†	12.5†	2.4	2.8	3.1
Education-levels[e]	I	II	III	I	II	III	I	II	III	I	II	III
Sample, *n*, and percentage (%)	221(16)	572(41)	603(43)	262(27)	396(41)	312(32)	532(59)	221(24)	147(16)	660(36)	570(31)	584(32)
Hypertension (%)	7.6	7.8	5.6	20.0	17.2	10.9†	9.5	9.3	10.1	13.0	10.5	12.0
BMI $\geqslant 25\,kg/m^2$ (%)	55.5	53.2	44.3†	72.2	74.0	66.1	74.3	69.9	64.8*	16.6	21.6*	22.9*
BMI $\geqslant 30\,kg/m^2$ (%)	29.0	27.1	18.0†	44.4	42.7	37.6	38.2	32.8	35.1	1.7	1.8	1.7
Light physical activity[b] (%)	83.5	65.2†	52.0†	87.7	80.0†	66.4†	89.3	76.6†	62.4†	24.1	34.0†	71.7†
Alcohol consumption[c] (%)	17.1	25.3*	38.2†	24.0	19.6	14.6†	11.3	18.7†	18.6*	5.4	3.9	4.9
Smoker[d] (%)	49.6	27.3†	17.2†	40.0	35.1	23.9†	16.9	16.0	13.2	3.5	2.4	2.2

*$p<0.05$, † $p<0.01$ from low-income or low education women of the same racial/ethnic group.

[a] Income tertiles were defined specifically for each racial/ethnic group.

[b] In the United States sample, light physical activity was defined as doing one or two leisure time activities during the past month or less. In China, light physical activity was defined as light or moderate occupation-based physical activity.

[c] Consumed alcohol one or more times per week.

[d] Current smoker at time of survey.

[e] Levels I, II, and III of education are equivalent to <12, 12, and >12 years, respectively, of education in the US. In China, the cut-offs were <3, 3–7 and >7 years.

behaviors were more common in the medium and high-income groups and low education group.

Table 2 shows the β-coefficients and intercept from logistic regression models used to predict hypertension. The size of the coefficient for each variable indicates the magnitude of effect and the sign indicates a positive or inverse association with hypertension. For example, having a high household income ($\beta = -0.876$) had an inverse association with hypertension for Whites, which was of greater magnitude than all the other variables except obesity ($\beta = 1.356$). This coefficient, however, represents the independent proxy effect of high income and does not fully describe its impact on hypertension. We know from pathway 1a in Fig. 1 that income also operates through other mediating factors and also that income generally has a synergistic association with education. Table 3 more fully describes the impact of SES on hypertension by showing how changes in SES (a combination of income and education) influence the predicted prevalence of hypertension through the proxy effect (pathway 1b) as well as through the measured risk factors (pathway 1a). The table shows that a simulated shift from observed levels of SES to low SES would increase the predicted prevalence of hypertension in all US-racial/ethnic groups, particularly Blacks. In Whites (+2.2%) and Blacks (+4.5%), most of this increase is due to the proxy effect of the SES; however, it is also partly mediated by changes in obesity prevalence (particularly for Whites) and physical activity (particularly for Blacks). The proxy effect of SES had very little impact on the predicted prevalence of hypertension for Mexican American women because, as can be seen in Table 2, income and education had more of an antagonistic association. Conversely, a shift from observed levels of SES to high SES would decrease the predicted prevalence of hypertension in each racial/ethnic group, but only marginally in Mexican Americans. In this group, positive associations with alcohol and smoking somewhat offset the benefits of less obesity and more physical activity. An increase in SES in China would lead to a small increase in hypertension (+0.2%) through increased obesity, but a decrease overall due to a strong SES proxy effect (−1.9%). In the US, the mediating effect of smoking was complex with current smoking status showing an inverse association with SES for each racial/ethnic group, but also an inverse association with hypertension in Whites and Mexican Americans. In Blacks, however, the association with hypertension was positive. Too few Chinese women smoked to be able to make comments about the association in this group.

Table 4 and Fig. 2 investigate the role SES plays in explaining racial/ethnic differences in the prevalence of hypertension within the US. These analyses are based on pooled data where income tertiles were defined using the full sample, rather than race-specific groups.

Table 4 shows the racial/ethnic differences in the prevalence of hypertension in terms of odds ratios. We present a simple model (model 1) that excludes income and education. Model 2 adds income and education variables. Collectively, these variables contributed significantly to the model (lrt, $p = 0.01$), attenuating the odds of hypertension in Blacks and Mexican Americans compared to Whites. A comparison of Models 3 and 4 shows that race–income and race–education interactions did not add significantly to the model (lrt, $p = 0.79$).

Table 2
β-Coefficients and intercepts from models used to predict the prevalence of untreated hypertension within ethnic groups

	United States			China
	Non-Hispanic White	Non-Hispanic Black	Mexican American	Chinese
Medium income	−0.617*	−0.470*	−0.195	−0.115
High income	−0.876†	−0.295	−0.375	0.001
Medium education	0.198	−0.038	0.130	−0.318
High education	0.131	−0.426	0.295	−0.258
Obesity[a]	1.356†	0.405*	0.314	0.972†
Light physical activity[b]	0.052	0.520*	0.436	0.074
Frequent alcohol consumption[c]	0.507*	0.428	0.183	−0.039
Smoker[d]	−0.267	0.233	−0.217	−0.369
Age	0.088†	0.073†	0.099†	0.073†
Intercept	−6.878†	−5.363†	−7.133†	−5.431†

*$p < 0.05$ †$p < 0.01$. Reference group = low income, low education. Predicted prevalence of hypertension = $[e^{(\acute{a} + \beta i Xi)}/1 + e^{(\acute{a} + \beta i Xi)}]$.

[a] Obesity was defined as a BMI $\geqslant 30\,kg/m^2$ United States and a BMI $\geqslant 25\,kg/m^2$ in China.

[b] Activity during leisure in the United States sample and during work in China.

[c] Consumed alcohol one or more times per week.

[d] Current smoker at time of survey.

Table 3
Simulating the impact of changes in SES within raceethnic groups on the average predicted prevalence of untreated hypertension, as mediated by measured and unmeasured risk factors[a]

	United States						China	
	Non-Hispanic White		Non-Hispanic Black		Mexican American		Chinese	
	($n=1396$)		($n=970$)		($n=900$)		($n=1814$)	
Predicted hypertension (%)	6.7		13.9		8.6		11.3	
Socio-economic Status	Low	High	Low	High	Low	High	Low	High
Obesity[b]	+0.4	−0.9	+0.1	−0.3	+0.1	−0.1	−0.7	0
Light physical activity[c]	+0.1	−0.1	+0.8	−1.1	+0.4	−0.7	−0.2	+0.2
Frequent alcohol consumption[d]	−0.4	+0.5	+0.2	−0.2	0	+0.2	0	0
Smoker[e]	−0.3	+0.1	+0.4	−0.5	−0.1	+0.1	0	0
Low SES proxy effect[f]	+2.2		+4.5		−0.1		+0.9	
High SES proxy effect[f]		−2.5		−1.3		0		−1.9
All risk factors	+2.0	−2.9	+6.0	−3.4	+0.3	−0.5	0	−1.7

[a] For example, holding the other variables constant, if all non-Hispanic White women had the obesity prevalence of low SES non-Hispanic White women (31.4%), the average predicted prevalence of hypertension would be 0.4% higher. If they all had the obesity prevalence of high SES non-Hispanic White women (15.2%), the average predicted prevalence of hypertension would be 0.9% lower.
[b] Obesity was defined as a BMI $\geqslant 30\,kg/m^2$ in the United States and a BMI $\geqslant 25\,kg/m^2$ in China.
[c] Activity during leisure time in the United States sample and during work in China.
[d] Consumed alcohol one or more times per week.
[e] Current smoker at time of survey.
[f] Measured using a composite of income and education where income was defined separately for each racial/ethnic group.

From this table, we conclude that income and education confounded, but did not modify, the association between race and hypertension and that they explain a small portion of the difference in the prevalence of hypertension between Blacks, Mexican Americans and Whites.

Fig. 2 displays the predicted impact (i.e., through pathways 1a *and* 1b in Fig. 1) of changes in income and education on hypertension in each of the ethnic groups. If all White women had the risk factor profile of women with low income and less than 12 years of education, their predicted prevalence of hypertension would be 11.1%, compared to 4.7% if they all had the risk factor profiles of those with high education and more than 12 years of education. The absolute change in hypertension with a shift from low (18.8%) to high SES (8.3%) in Blacks was larger than in Whites, but relatively speaking their health gain from an increase in SES was similar. It is important to note that even at the highest levels of income and education, the prevalence of hypertension in Blacks was not much lower than that in Whites at the lowest levels of income and education. This supports our earlier observation that SES explains part, but not all, of the difference in prevalent hypertension that exists between these two ethnic groups. A simulated increase in SES also lowered the predicted prevalence of hypertension in Mexican American women but not to the same extent.

Discussion

Variations in income and education have different effects depending on a country's stage of development and on ethnic sub-population

Consistent with most data from developed countries, we found an inverse association between SES and hypertension among US women that varied with ethnic group. Investigation of the mediating risk factors revealed important racial/ethnic differences that help explain stronger inverse associations observed in Blacks (Shakoor-Abdullah, Kotchen, Walker, Chelius, & Hoffman, 1997), and the inconsistent SES–hypertension associations observed for Mexican Americans (Hazuda, 1996). Our data suggest that the strength of the association for Blacks is not only due, in large part, to unmeasured risk factors associated with SES but also to a consistent positive association through obesity, light physical activity, alcohol consumption and smoking. The inconsistent associations for Mexican American women may be because an increase in SES simultaneously has a beneficial (through lower obesity and more physical activity), detrimental (through alcohol consumption and smoking) and a neutral effect (through the SES proxy) on hypertension. The neutral proxy effect, may be due to the varying influence of sociocultural factors, such as the degree of acculturation or modernization (Franco et al., 1985).

Table 4
Modeling racial/ethnic differences in the odds of untreated hypertension: the impact of socioeconomic status (SES) as an effect modifier and as a confounder

	Model 1 Without SES	Model 2 With SES	Model 3 Without raceSES interactions	Model 4 With race SES interactions ‡
Non-Hispanic White	1 (referent)	1(referent)	1 (referent)	1 (referent)
Non-Hispanic Black	2.20 (1.65–2.92)	1.97 (1.47–2.64)	1.77 (0.87–3.62)	1.95 (0.74–5.11)
Mexican American	1.37 (1.02–1.85)	1.19 (0.86–1.65)	1.49 (0.66–3.37)	1.18 (0.43–3.22)
Obese	2.03 (1.60–2.58)	1.95 (1.54–2.49)	3.72 (2.48–5.57)	3.72 (2.48–5.59)
Light physical activity	1.42 (1.06–1.91)	1.31 (0.97–1.78)	1.08 (0.70–1.67)	1.09 (0.70–1.69)
Frequent alcohol consumption	1.46 (1.11–1.92)	1.49 (1.13–1.97)	1.61 (1.04–2.50)	1.60 (1.03–2.49)
Smoker	1.05 (0.81–1.38)	0.98 (0.75–1.29)	0.79 (0.49–1.26)	0.79 (0.49–1.27)
Age	1.09 (1.08–1.10)	1.09 (1.08–1.10)	1.09 (1.08–1.10)	1.09 (1.08–1.10)
Medium income[a]		0.76 (0.58–1.00)	0.75 (0.57–0.99)	0.67 (0.48–0.93)
High income[a]		0.60 (0.42–0.85)	0.59 (0.41–0.84)	0.57 (0.37–0.86)
Level II education[b]		1.12 (0.83–1.49)	1.11 (0.83–1.49)	1.16 (0.68–1.98)
Level III education[b]		0.88 (0.62–1.26)	0.92 (0.64–1.32)	0.99 (0.54–1.81)
Black * Obese			0.40 (0.23–0.71)	0.40 (0.23–0.70)
Mexican American*Obese			0.36 (0.20–0.65)	0.36 (0.20–0.66)
Black * Light			1.57 (0.79–3.12)	1.50 (0.74–3.01)
Mexican American * Light			1.34 (0.60–3.03)	1.41 (0.62–3.22)
Black * Alcohol			0.98 (0.52–1.84)	0.97 (0.51–1.83)
Mexican American * Alcohol			0.76 (0.35–1.62)	0.76 (0.35–1.65)
Black * Smoker			1.61 (0.86–3.01)	1.57 (0.83–2.96)
Mexican American * Smoker			1.02 (0.47–2.22)	1.01 (0.46–2.20)
Black * Medium income				1.17 (0.55–2.50)
Black * High income				0.84 (0.23–3.12)
Mexican American * Med income				1.62 (0.84–3.12)
Mexican American * High income				0.88 (0.14–5.29)
Black * level II education				0.82 (0.34–1.95)
Black * level III education				0.76 (0.28–2.03)
Mexican American * level II education				0.72 (0.30–1.72)
Mexican American * level III education				1.12 (0.38–3.32)
Likelihood-ratio test (lrt)	$p=0.01$ cf. model 2		$p=0.79$, cf. model 4	

*Indicates the interaction between the two variables.

[a] Income thirds were defined for the pooled sample.

[b] Levels I, II, and III of education are equivalent to <12 years, 12 years, and > 12 years of education, respectively. Cf: compared with.

In China, a country at a much lower level of income and education than the US, we found a U-shaped association between SES and hypertension. The mediating risk factors (obesity and light physical activity) and proxy SES effects offset each other to some extent, leading to this result. This pattern is consistent with findings from Brazil (Monteiro, Benico, Conde, & Popkin, 2000) and some of our earlier work from China (Bell, Ge, & Popkin, 2001), where we have observed that both countries may be further along the nutrition

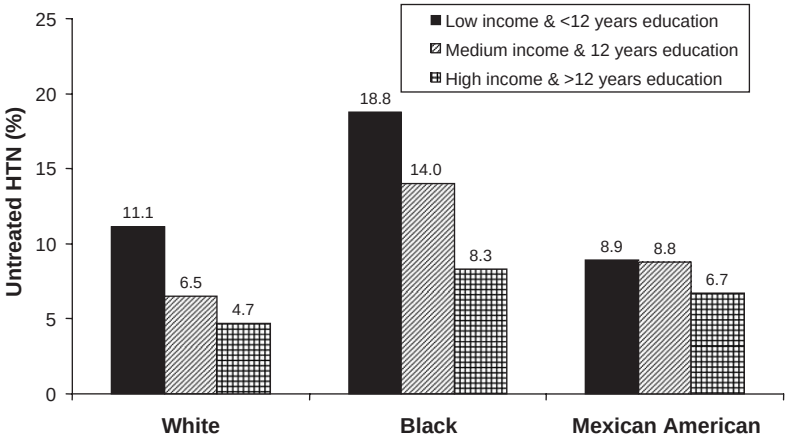

Fig. 2. The combined effect of income and education on the predicted prevalence of hypertension (HTN) in US women by ethnic group (based on model 2 in Table 4).

transition than other developing countries and that risk factor gradients are beginning to invert. (Popkin, 2002)

Income and education help to explain hypertension differences between US racial/ethnic groups

Differences in income and education made an important contribution to differences in the prevalence of hypertension between Blacks and Whites, but they did not explain the full picture. Higher levels of income and education would lower the prevalence of hypertension for women from all ethnic groups, but Blacks would still have a much higher prevalence than Whites. In other words, if there were no SES disparities between Blacks and Whites, and women from both racial/ethnic groups had high income and education levels, hypertension would still be almost twice as prevalent among Blacks (8.3% vs. 4.7% for Whites). Conversely, if all Whites had a low SES profile, as is the reality for a majority of US Blacks, only 11.1% would be hypertensive compared to 18.8% of Blacks. This does not automatically imply, however, that the remaining difference is due to a genetic predisposition to hypertension among Blacks. The cross-sectional design of this study precludes such a causal inference. Further, each race/ethnic group lives in a different social environment, and the biological relationship captured in the hypertension prediction equation is specific to this environment. Moreover, we cannot account fully for either unmeasured or poorly measured explanatory factors—the SES proxy effect. As Cooper and Kaufman (1998) have asserted, race is a complex biological and social construct. Our results are subject to residual confounding, arising from the ill-defined nature of both race and SES. In other words, race may be picking up some of the variation in hypertension that is due to social factors.

There is some evidence for a genetic predisposition to hypertension among both Blacks and Whites (O'Donnell & Kannel, 1998). Aviv and Gardner (1989) noted that Black populations may have an increased salt sensitivity compared to White populations. Whites, on the other hand, may have a stronger association between BMI and hypertension (Bell, Adair, & Popkin, 2002).

We did not observe evidence that SES modifies the association between race and hypertension as Dressler (1990) and the Hypertension Detection and Follow-up Program Cooperative Group (1977) did. However, in light of the difficulties that exist in defining both race and SES, such interactions remain extremely difficult to confirm or interpret.

The impact of a change in SES on hypertension should be monitored over time to truly measure association. Thus, the cross-sectional data and statistical models used in this study can only offer suggestions as to possible mechanisms. Also, our numerators were small, which may have obscured important statistical associations. Finally, differences between the data from China and the US prevented us from being able to conduct a broader analysis of SES differences between ethnic groups, mediating risk factors and their effect on hypertension.

It is easy to oversimplify associations between SES and hypertension. SES is often included in models without due consideration to the pathways through which it acts, or to the potential for interactions among income, education and the other variables commonly used to define it. We have noted that differences in hypertension by country and racial/ethnic group can be partially explained by differential effects of SES on mediating risk factors. In the US, disparities in income and education between White, Black and Mexican American women explained some of the differences that exist in hypertension between these racial/ethnic groups.

Improvements in SES would lower hypertension in each ethnic group, but particularly in Blacks, who have a high prevalence of hypertension and low SES compared to Whites.

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