Systolic Blood Pressure, Socioeconomic Status, and Biobehavioral Risk Factors in a Nationally Representative US Young Adult Sample

Beverly H. Brummett, Michael A. Babyak, Ilene C. Siegler, Michael Shanahan, Kathleen Mullan Harris, Glen H. Elder, Redford B. Williams

See Editorial Commentary, pp 140–141

Abstract—In the National Longitudinal Study of Adolescent Health, a US longitudinal study of >15 000 young adults, we examined the extent to which socioeconomic status is linked to systolic blood pressure (SBP) and whether biobehavioral risk factors mediate the association. More than 62% of the participants had SBP >120 mm Hg and 12% had SBP >140 mm Hg. More than 66% were classified as at least overweight (body mass index >25 kg/m^2), with >36% meeting criteria for at least class I obesity (body mass index >30 kg/m^2). Multivariate models showed that higher household income and being married were independently associated with lower SBP. Higher body mass index, greater waist circumference, smoking, and higher alcohol intake were each independently associated with higher SBP. Meditational analyses suggested that higher education level was associated with lower SBP by way of lower body mass, smaller waist circumference, and lower resting heart rate. When these indirect effects were accounted for, education was not significantly associated with SBP. In contrast, household income remained associated with SBP even with control for all of the covariates. Results reinforce current public health concerns about rates of obesity and high blood pressure among young adults and suggest that disparities in education level and household income may play an important role in the observed decrements in health. Identifying modifiable mechanisms that link socioeconomic status to SBP using data from a large representative sample may improve risk stratification and guide the development of effective interventions. **(*Hypertension*. 2011;58:161-166.) ● Online Data Supplement**

Key Words: systolic blood pressure ■ socioeconomic status ■ education ■ income ■ body mass index ■ biobehavioral risk

High blood pressure continues to be prevalent in the United States, conferring increased morbidity and mortality, for example,[1,2] and remains a significant economic burden on the healthcare system.[3] Recently much attention has been paid in the scientific literature[4] and popular press[5] to substantial increases in the prevalence of biobehavioral risk factors for high blood pressure among young adults. Although advances in treatment of high blood pressure have apparently stabilized the rates of high blood pressure for the present,[6] further elucidating how modifiable biobehavioral risk factors are related to high blood pressure may provide additional opportunities for maintaining or improving on these advances in this population.

Modifiable biobehavioral risk factors for high blood pressure include body mass index (BMI), waist circumference, heart rate (HR), alcohol consumption, exercise, and smoking.[7] Lower socioeconomic status (SES) also has been associated with a poorer biobehavioral risk profile and, in turn, with higher systolic blood pressure (SBP).[8–10] Recent evidence from a French sample aged 30 to 79 years[10] has shown that body shape, HR, and health behaviors may account for a sizable amount of the association between SES and SBP. In the present study, we adopted the theoretical framework used in the French study[10] to further examine the association between SES and SBP using data from a nationally representative sample of ≈15 000 young adults in the United States. Our aims were to assess the independent predictive association among SES indices, biobehavioral factors, and SBP and to examine these biobehavioral risk factors as possible mediators of the association between SBP and SES. We focused on SBP in the present study, because SBP has been shown to be more important than diastolic blood pressure with respect to health risk[11–13] and also possibly to be more responsive than diastolic blood pressure to changes in mod-

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ifiable risk factors.[14] Results from the present study could improve risk stratification in clinical settings and inform interventions aimed at reductions in social disparities in health and also further inform the generalizability of the association between SES and SBP across cultures and age cohorts.

Methods

Participants

The current study uses data from the National Longitudinal Study of Adolescent Health, a nationally representative sample of ≈15 000 young adults that was designed to assess the effects of health-related behaviors during adolescence and into young adulthood. The study was reviewed and approved by the institutional review board at the University of North Carolina-Chapel Hill. Written consent was obtained for all of the data collection. The participants were followed from grades 7 through 12 in 1995 through early adulthood in 2008 in 4 waves of data collection.[15] Participants without SBP measures or survey sample weights were excluded, leaving a final sample of 14 299.

Measures

Demographic Measures

Age and marital status (yes/no) were recorded assessed at Wave IV. Race was constructed from a series of queries at Wave I.

SBP, Resting HR, and Cardiac Medication Use

Certified field interviewers measured respondents' resting, seated systolic, and diastolic blood pressures (in millimeters of mercury) and pulse rate (in beats per minute).[16] After a 5-minute seated rest, 3 serial measurements were performed at 30-second intervals using a factory calibrated, MicroLife BP3MC1-PC-IB oscillometric blood pressure monitor (MicroLife USA, Inc, Dunedin, FL), and SBP was constructed as the average of measures 2 and 3 and are highly reliable.[17] Cardiac medication status was assessed at the Wave IV in-home interview.

BMI and Waist Circumference

Height, weight, and waist circumference were assessed at Wave IV. BMI was calculated as BMI=weight (in kilograms)/height (in meters squared). BMI was modeled in its continuous form in our primary analyses, but for descriptive purposes also was reported in the following categories: (1) BMI <25.0=normal weight; (2) 25.0 to 29.9=overweight; (3) 30.0 to 34.5=obese class I; (4) 35.0 to 39.5=obese class II; and (5) ≥40.0=morbidly obese.[18] Waist circumference was measured to the nearest 0.5 cm at the superior border of the iliac crest.[16]

Physical Exercise, Alcohol Consumption, and Smoking Behavior

Exercise was represented by a yes/no variable that assessed regular (on a weekly basis) participation in any bouts of physical activity, such as walking or strenuous sports.[19] Alcohol consumption was defined as follows: 0=nondrinker; 1=occasional drinker, drink ≤2 days of the week; 2=light, drink 5 to 7 days per week and ≤2 drinks (≤1 if female); 3=moderate, drink 5 to 7 days per week, 3 drinks for males and 2 drinks for females; and 4=heavy, drink 5 to 7 days per week, >3 drinks for males and >2 for females. Smoking was coded yes/no, indicating current daily smoking. All of the above variables were assessed at Wave IV, concurrent with the SBP measurement.

Individual and Parental Education

Education was coded as the highest level reported (at Wave IV for respondent and Wave I for parent), as follows: 1=some high school or less; 2=graduated high school; 3=some college or vocational tech; 4=bachelor's degree; and 5=some graduate school or more. Participants completing General Educational Development tests were grouped in the lower level of education class.[20]

Financial Strain, Home Ownership, Built Environment, and Household Income

Income, financial strain, and home ownership were assessed at Wave IV. Financial strain was derived from 6 questions that assessed whether individuals reported the inability to pay bills, buy food, and so forth. A "built environment" measure (rated by the field interviewer) was the sum of 2 Likert-type items assessed at Wave I regarding how well the building in which the respondent lived was maintained and the surrounding buildings were maintained. The summed score had a possible range of 2 to 8, with higher scores reflecting poorer maintenance. Annual household income was assessed using ordered categories. To create an ordinal income measure, we assigned the midpoint value to each category, resulting in the 13 values ranging from $2500 to more than $150 000.

Statistical Analysis

Sample characteristics were described as median (interquartile range) for continuous variables and frequency (percentage) for categorical measures. Analyses were carried out using SAS version 9.2 (SAS Institute Inc, Cary, NC), R software (http://cran.r-project.org), and Mplus.[21] Statistical models were weighted using grand sample weights and adjusted for individual school membership. We first conducted a series of linear regression models estimating the independent associations between the predictor variables and SBP, first adjusted for only age, sex, and cardiac medication, and then adjusted for all of the predictors under study, a "full" model. To capture nonlinearity for several variables we used a piecewise regression or "hockey stick" approach.

We then estimated a path model in which the associations between respondent education and household income on SBP were mediated by the biobehavioral variables. Significance tests were 2 sided, and a value of $P<0.05$ was considered "significant."

Further details on the above assessments and statistical analyses can be found in the online Data Supplement at http://hyper.ahajournals.org.

Results

Table 1 shows the unweighted sample characteristics. The majority of participants were white women, with mean age of 29 years. Median SBP was 123.5 mm Hg, and median BMI was 27.6. Approximately 3.7% of the sample was taking some form of cardiac medication. More than 62% of the participants had SBP >120 mm Hg and 12% had SBP >140 mm Hg. More than 66% were classified as at least overweight (BMI: 25.0 to 29.9).

Predictors of SBP

Among the background variables, black race/ethnicity, male sex, age, and taking cardiac medication were positively associated with higher SBP (see Table 2). Adjusting only for age, sex, and cardiac medication, financial strain, built environment, alcohol intake, tobacco smoking, BMI, resting HR, and waist circumference were associated with SBP, whereas higher respondent and parental education, owning a home, being married, regular exercise, and annual household income were inversely associated with SBP.

In the fully adjusted model, the background variables age, male sex, cardiac medication use, and black race remained significantly, positively associated with SBP. Annual income and being married maintained their significant negative association with SBP, whereas moderate and heavy alcohol intake remained strongly associated with higher SBP. Cigarette smoking also was associated with higher SBP. Strong, independent associations were observed for BMI and waist circumference (see Figure 1), with higher values correspond-

Table 1. Descriptive Statistics (N=14 299)

Background Variable	N	Median or Percentage	Interquartile Range or Frequency
SBP, mm Hg	14 299	123.5	115.0, 132.5
Age, y	14 299	29.0	28.0, 30.0
Men	14 299	47%	6713
Race	14 288		
Hispanic		16%	2221
Black		22%	3091
Asian		6%	914
Native American		2%	257
Other		1%	125
White		54%	7680
Cardiac medication	14 299	4%	523
Financial strain	14 292	25%	3525
Married	14 282	50%	7189
Annual household income ($US×1000)	13 368	62.5	33.0, 87.5
Own home	14 276	41%	5822
Built environment (scale 2 to 8, best to worst)	14 131	3.0	2.0, 4.0
Respondent education	14 295		
Less than high school		8%	1108
High school		16%	2296
Some college		44%	6315
College		20%	2814
Postgraduate		12%	1762
Parent education	14 079		
Less than high school		15%	2141
High school		23%	3212
Some college		29%	4113
College		18%	2582
Postgraduate		14%	2031
Heart rate (pulse), bpm	14 218	73.5	66.0, 81.5
Body mass index, kg/m^2	14 160	27.6	23.7, 32.8
Waist circumference, cm	14 241	95.0	86.0, 107.0
Alcohol use	14 201		
Never		27%	3887
Occasional		62%	8758
Light		3%	425
Moderate		2%	336
Heavy		6%	795
Exercise	14 288	85%	12 114
Smoking	14 183	22%	3059

N represents the No. of nonmissing cases. Note that values are unweighted. SBP indicates systolic blood pressure.

ing with higher SBP. Higher resting HR was also associated with higher SBP, although the *P* value was 0.06.

Mediation path model results are displayed in Figure 2. Estimates for respondent education (top panel) and household income (bottom panel) were produced from a single model that included all of the variables simultaneously but are separated in Figure 2 for presentational clarity. Higher levels of respondent education were associated with lower BMI, lower resting HR, less smoking, and more frequent exercise. Higher education level was associated with greater alcohol intake. The indirect effects of respondent education through BMI and through resting HR were statistically significant (see Table S2, available in the online Data Supplement at http://hyper.ahajournals.org). For every one category increase in education, there was roughly a 0.50-mm Hg decrease in SBP by way of BMI and a 0.20-mm Hg decrease by way of resting HR. In contrast, for every one level increase in education, there also was a 0.13-mm Hg increase in SBP by way of alcohol intake. The indirect effects of education through exercise and smoking were not statistically significant. Waist circumference and BMI were not simultaneously modeled because of their strong correlation. We, therefore, re-estimated the primary path model replacing BMI with the waist measure. In this model, education was inversely associated with waist circumference (unstandardized path coefficient=−2.71; 95% CI=−3.20 to −2.26). The unstandardized indirect effect for education via waist was −0.64 (95% CI=−0.76 to −0.53). (The primary path model also specified indirect effects of education on SBP by way of household income and biobehavioral variables; these associations were all trivial in magnitude and not statistically significant.) The overall indirect effect of education across the entire set of biobehavioral variables was −0.91 (95% CI=−1.19 to −0.63). Finally, after accounting for all of the indirect effects via biobehavioral mediators, the direct effect of respondent education on SBP was no longer statistically significant. Combining the direct effect with all of the indirect effects yielded a total effect for education on SBP of −0.59 (95% CI=−0.91 to −0.26).

Higher household income was associated with lower resting HR and higher alcohol intake (see Figure 2). In contrast to respondent education, although the specific indirect effects of income by way of alcohol and resting HR were statistically significant (see bottom section of Table S2), the total indirect effect was not. Moreover, the direct effect was statistically significant, with each $50 000 increase associated with a decrease in SBP of ≈0.61 mm Hg. The total effect of household income on SBP was −0.74 (95% CI=−1.19 to −0.29) and statistically significant. As with BMI, income was inversely associated with waist circumference (unstandardized path coefficient=−1.71; 95% CI=−2.43 to −1.03). The unstandardized indirect effect of household income on SBP via waist circumference was also significant (−0.41; 95% CI=−0.54 to −0.24).

Discussion

A striking number of these young adults displayed clinically relevant elevations in both SBP and BMI. Among the most noteworthy findings from the conventional regression model was that, among the SES indices, only income and marital status remained significantly related to SBP after adjustment for biobehavioral risk factors and other SES indicators. Our findings regarding the mediating path from education level to SBP by way of BMI, resting HR, and alcohol consumption are consistent with those of Chaix et al.[10] However, our

Table 2. Unstandardized Regression Coefficients From Regression Models

	Initial Model (Age, Sex, Medication Adjusted)		Full Model (All Potential Predictors Under Study)	
Predictor	Regression Coefficient	95% Confidence Limits	Regression Coefficient	95% Confidence Limits
Background factors				
Race				
Hispanic	0.21	−0.61, 1.03	−0.49	−1.29, 0.30
Black	2.14‡	1.39, 2.92	1.14†	0.39, 1.89
Asian	−0.80	−2.12, 0.52	0.73	−0.52, 1.98
Native American	1.40	−0.11, 2.91	0.48	−0.95, 1.91
Other	−2.43	−4.57, −0.30	−1.37	−3.42, 0.67
White (reference)	…		…	
Age (10 y)	2.38†	0.77, 4.00	1.93*	0.38, 3.48
Men	9.90‡	9.49, 10.30	9.07‡	8.65, 9.49
Cardiac medication	6.72‡	5.65, 7.78	4.17‡	3.15, 5.20
SES indices				
Married	−1.52‡	−1.96, −1.08	−1.21‡	−1.66, −0.77
Household income ($50 000)	−0.90‡	−1.10, −0.51	−0.35*	−0.66, −0.04
Own home	−0.80‡	−1.22, −0.35	0.09	−0.35, 0.54
Financial strain	0.50*	0.02, 0.98	−0.42	−0.90, 0.07
Parent's education				
No high school (reference)	…		…	
High school	0.24	−0.46, 0.94	0.21	−0.47, 0.86
Vocational tech	−0.32	−1.01, 0.37	−0.23	−0.90, 0.44
College	−1.22†	−2.00, −0.45	−0.33	−1.10, 0.44
At least some postgraduate	−1.32†	−2.18, −0.46	−0.23	−1.11, 0.64
Participant's education				
No high school (reference)	…		…	
High school	0.45	−0.39, 1.29	0.06	−0.74, 0.86
Vocational tech	−0.46	−1.22, 0.30	−0.69	−1.44, 0.05
College	−1.22†	−2.09, −0.36	−0.21	−1.11, 0.69
At least some postgraduate	−1.40†	−2.36, −0.44	0.11	−0.88, 1.11
Built environment	0.26†	0.12, 0.40	0.05	−0.09, 0.19
Biobehavioral factors				
Regular exercise	−0.91†	−1.50, −0.32	−0.56*	−1.12, −0.002
Alcohol intake				
None (reference)	…		…	
Occasional	0.43	−0.06, 0.92	0.88‡	0.39, 1.36
Light	−0.12	−1.38, 1.14	1.47*	0.22, 2.73
Moderate	3.73‡	2.30, 5.15	5.31‡	3.92, 6.70
Heavy	3.92‡	2.99, 4.85	4.51‡	3.62, 5.41
Current smoking	0.53*	0.03, 1.02	0.61*	0.11, 1.11
BMI <32 (per 1 unit)	0.82‡	0.77, 0.87	0.65‡	0.56, 0.74
BMI ≥32 (per 1 unit)§	−0.52‡	−0.61, −0.43	−0.42‡	−0.54, −0.30
Resting heart rate <72 (per 10 bpm)	0.95‡	0.54, 1.36	0.09	−0.30, 0.49
HR ≥72 (per 10 bpm)§	0.38	−0.21, 0.97	0.53	−0.03, 1.09
Waist circumference <100 cm (per 10 cm)	0.32‡	0.30, 0.35	0.91‡	0.50, 1.32
Waist ≥100 (per 10 cm)§	−0.16‡	−0.20, −0.12	−0.57*	−1.10, −0.05

Values in parentheses next to continuous predictors represent points of comparison along regression line. For example, for the first set of models reported in column 2, each $50 000 increase in annual income is associated with an ≈0.90-mm Hg reduction in SBP. SBP indicates systolic blood pressure; BMI, body mass index; HR, heart rate; SES, socioeconomic status.

*P=0.05.

†P=0.01.

‡P=0.001.

§Coefficients involving BMI, waist circumference, and heart rate are from a linear piecewise (hockey stick) estimate in which the regression slope is allowed to bend once at an inflection point. This procedure generates 2 coefficients for each variable, each coefficient representing the 2 different slope regions. For example, in column 1, the coefficient for waist circumference <100 (second column) is ≈0.32, which is the regression slope for individuals whose waist circumferences is ≤100 cm. The coefficient for waist circumference ≥100 represents the change in that slope for individuals whose waist circumference is >100 cm. Above 100 cm, the slope is −0.16 less steep than the slope for waist circumference <100 cm, that is, the slope for waist circumference beyond 100 cm is 0.33+(−0.16)=0.14.

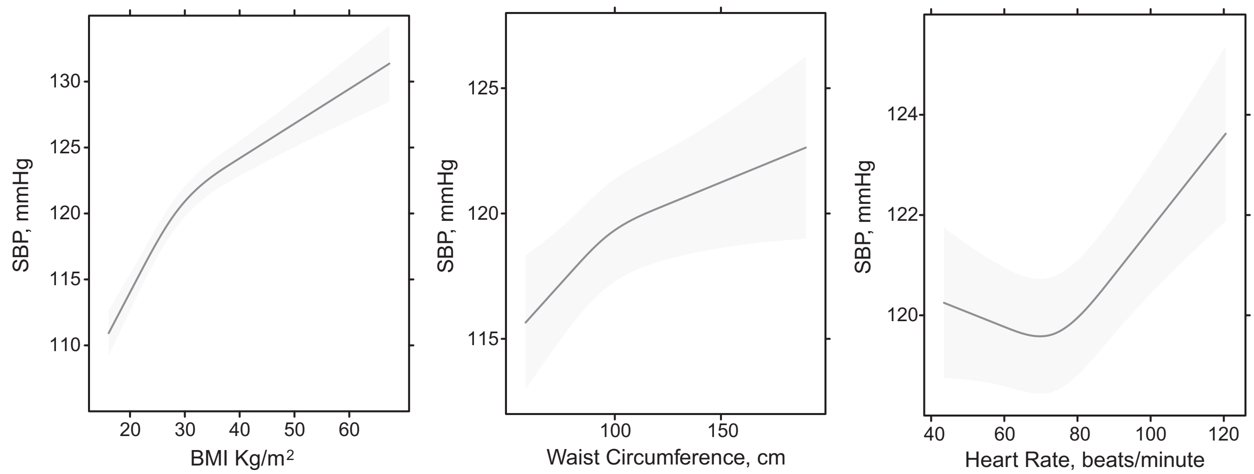

Figure 1. Predicted systolic blood pressure (SBP) as a function of body mass index (BMI), waist circumference, and resting heart rate for a typical participant (white, female, unmarried, unmedicated, with some college education, and average values of remaining covariables). Shaded area represents 95% CIs for regression estimate.

findings diverge from the French study in that we did not find that the total effect of household income on SBP was accounted for by these indirect biobehavioral mediators. This discrepancy may be the result of cultural differences between French and American cultures, the younger age of our sample, and/or our larger sample size. In addition, the availability of government-sponsored healthcare in France, for example, could have buffered the SBP-raising effects of lower household income there. Another intriguing possibility is that the recent economic recession resulted in loss of jobs and diminished household income among National Longitudinal Study of Adolescent Health participants at just about the time that the Wave IV data collection was under way, thereby potentiating the impact of such a recent reduction in household income on SBP. Supporting this possibility is the recent report[22] that there was an increase in acute myocardial infarction rates during the stock market decline of October 2008 to April 2009.

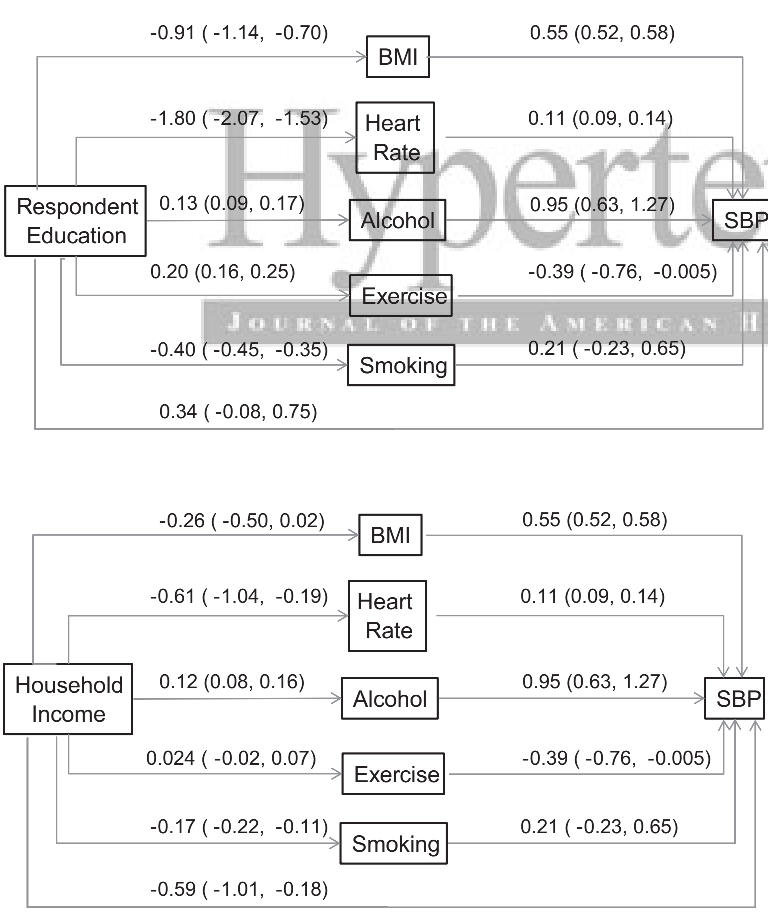

Figure 2. Results of path model estimating indirect effects from education and income to systolic blood pressure (SBP) by way of biobehavioral variables. Values are unstandardized path weights with 95% confidence limits. Weights can be interpreted in original metric of the variable. Linearity was assumed for all associations. Results were estimated simultaneously from the same model but separated here for presentational clarity.

Our findings may have important implications for approaches to prevention of high blood pressure. Mediation of the low education association with SBP via increased BMI and waist circumference is consistent with the long-recognized importance of steps to decrease BMI and central obesity in any cardiopreventive program. The independent effect of lower HR to mediate the effects of both low education and household income on SBP points to the importance of also identifying interventions that can reduce resting HR. One such intervention is aerobic exercise, which is also long recognized as an important cardiopreventive measure.

Finally, the emergence of smoking, being married, and increased alcohol consumption as independent correlates of SBP points to the importance of smoking cessation and limiting alcohol consumption as potentially important preventive approaches. The salutatory effects of marriage and social support in general have been widely studied, for example,[23] with the majority of findings being consistent with ours.

The cross-sectional nature of this study precludes conclusions regarding causality, and the present findings may generalize only to individuals 24 to 32 years of age. In addition, as with any observational study, unmeasured factors may have significantly contributed to the present associations. For example, genetic profiles could be associated with SES, as well as SBP.

Perspectives

We have shown that indices of lower SES are associated with increased SBP and that increased BMI and waist circumference and higher resting HR are significant mediators of these associations. These findings strengthen the case that lower SES is a risk factor for cardiovascular disease and that increased BMI and central obesity are important mediators of this effect. Interventions that promote weight loss and reduce resting HR have the potential to reduce the impact of low SES on SBP, especially among young adults, which will further reduce the cardiovascular health burden of the US population as they age into middle and older adulthood.

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Disclosures

None.

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Table of Contents:

1) Additional notes on study sample
2) Additional notes on measures
3) Notes on statistical analysis
4) Mplus code
5) References
6) Table S1: Medication data
7) Table S2. Indirect effects from education and income to SBP

Additional notes on study sample

The current study used data from a nationally representative sample of young adults—Add Health— or the National Longitudinal Study of Adolescent Health—that was designed to study health and developmental trajectories across the life course from adolescence to adulthood. The participants have been followed from grades 7 through 12 in 1995 through early adulthood in 2008. Participants were enrolled in one of 80 schools in the United States and data are also available from multiple sources, including parent interviews and assessments of community characteristics [1]. Study schools were selected to represent a stratified sample based on region, suburban/urban/rural, school type (public, private, or parochial), ethnic composition, and size. Wave I data collection occurred in 1994-95 and included a confidential in-school survey collected from 90,118 students grades 7 to 12. Approximately 80% of the schools that participated provided a roster from which students were randomly picked to participate in a 1 ½ hour in-home interview, resulting in a sample of 20,745 students aged 11 to 19. The in-home interview wave was conducted between April and December of 1995 and included the target child and one parent or parent-figure. Similarly, Wave II was conducted on the students who were in 7^{th} to 11^{th} grade during the first wave and occurred between April and August of 1996--yielding a sample of 14,738 adolescents ages 13 to 20. Wave III was conducted between August 2001 and April 2002 and included participants from Wave I, resulting in sample of 15,197 ages 18 to 26. SBP was assessed at Wave IV, which was conducted between April 2007 and February 2009 and included participants from Wave I, resulting in sample of 15,701 participants. Those without SBP measures or without sample weights were excluded from the present study, leaving 14,199 participants ages 24 to 34for the present analysis.

Additional notes on measures

The original biological sex variable was recoded as the variable “male” where 0=female and 1=male. Marital status was coded as 0= never married, and 1=ever married at Wave IV.

A single race variable was constructed from the responses to the following six questions asked at Wave I: 1) “Are you of Hispanic or Latino origin?”; 2) “What is your race? White”; 3) “What is your race? Black or African American”; 4) “What is your race? American Indian or Native American”; 5) “What is your race? Asian or Pacific Islander”; or 6) “What is your race? Other.”

Parental education was determined by two sources, from the adolescent in-home interview at Wave 4 and from the parent during an in-home parental interview conducted at Wave I. Self-reported education from the parental interview was typically supplied by the mother or female head of household. When data from both sources (adolescent and parent) were available, reports from the parent interview were used. Mother’s and father’s education level were combined into a variable that represented the highest level of education attained by either parent. This variable was coded into 5 classes that followed the approach used for adolescent level of education.

Self-reported financial strain was derived from a summary measure from 6 questions that assessed whether individuals reported the inability to pay bills, buy food, pay utilities, etc. Report of no inability across all items was scored 0, whereas a yes to one or more of the items was scored 1. Home Ownership was coded as 0= do not own a home, 1= own a home. Income, Financial Strain, and Home Ownership were assessed from questions at Wave IV. A “Built Environment” measure (rated by the study interviewer) was constructed by taking the sum of two items assessed at Wave I regarding: 1) how well the building in which the respondent was maintained, and 2) how well the surrounding buildings were maintained. These items were measured on an 4 point Likert-type response scale with higher scores reflecting poorer maintenance. The final summed score has a range of 2-8. To ascertain household income, participants were asked, “Thinking about your income and the income of everyone who lives in your household and contributes to the household budget, what was the total household income before taxes and deductions in (2006/2007/2008)? Include all sources of income, including non-legal sources.” Household income was represented by a variable that was originally in ordered categories. In order to approximate a continuous variable from the ordered categories, were assigned the midpoint of each category to a score in the given category (e.g., a value of 2,500 was assigned to individuals reporting between $0 and $5,000, a value of $125,000 to individuals reporting $100,000-149,999, etc. Income reported as > $150,000 was assigned the value $150,000). The resulted in the following possible values 2,500, 7,500, 12,500, 17,500, 22,500, 27,500, 35,000, 45,000, 62,500, 87,500, 12,5000, and 150,000. IN the regression analyses, we further rescaled these values by dividing by 50,000.

Exercise. The definition of regular exercise is measured using a standard physical activity behavior recall[2]. Lack of exercise, or no physical activity, is defined by self-reports of no bouts of moderate to vigorous physical activity (5-8 metabolic equivalents) across 7 groups of activities per week [3].

Cardiac medication. Participants were first asked, “Have you taken in medications in the last four weeks?” If the respondent answered yes, they were asked to collect their medications and the interviewer recorded a list of medications provided. If the respondent was not able to provide medications, medication status was documented based on the respondents recollection. We represented medication use with a yes/no variable. In addition to anti-hypertension medications we also included any other cardiovascular medication that would tend to lower blood pressure.

For our medication indicator variable, we included any medication in the cardiovascular class that was known to lower blood pressure. Participants taking one or more of these medications was coded on the Cardiac Medication variable as ‘1’ and the remainder were coded as 0. The medications for our sample appear in Table S1. Because a participant may have been taking more than one medication of this class the total number of medications exceeds the number of participants on at least one medication.

Notes on statistical analysis

All statistical models incorporated grand sample survey weights and also adjusted for individual school membership, thus adjusting for survey design effects of individuals clustered in the sampling unit of school and stratification of geographic region. Application of poststratification weights allows the results to be generalized to adults of similar age and background in the U.S. population.

Assessing nonlinearity: We used the rms package in R (http://cran.r-project.org) to conduct preliminary analyses of the linearity assumptions of the model. The rms package includes the option to model continuous covariates as nonlinear using a flexible, nonparametric algorithm called a restricted cubic spline [4]. Restricted cubic splines have many desirable properties, including imposing restrictions such that relatively few degrees of freedom are expended in determining the functional form of the regression line. In the case of BMI, waist circumference, and resting heart rate, we specified that the spline would have 3 knots. Unlike linear splines, however, the knots do not necessarily reflect inflection points (i.e. locations where the regression line turns). The knots in this case simply reflect locations where the piecewise cubic functions are joined. Stone [5] has shown that the location of the knot is not particularly important in terms of recovering the functional form of an association. We used the default knot locations in the rms package of the .10, .50, and .90 quantiles. Because spline coefficients can be hard to directly interpret, we simplified our model by developing a linear piecewise function for each of the above three variables, allowing the line to bend at the location suggested by the spline plots.

We also examined the assumption of additivity by testing a prespecified set of interactions between each of the biobehavioral variables (exercise, BMI, waist, heart rate, and smoking) and race, region, age, and gender. The inclusion of these terms explained only an additional 0.7% of the variance in SBP. A pooled test for this R-square difference between a model with the interactions and one without at 211-161 = 50 degrees of freedom is not statistically significant.

Missing Data: Missing data for the primary regression models were imputed using PROC MI in SAS with 50 imputations. The imputation model included all variables in full model, with binary variables rounded to nearest integer. We then estimated a general linear model using SAS PROC GLM for each of the imputed datasets. Regression estimates, and their 95% confidence intervals and p-values were then calculated from the GLM results using SAS PROC MIANALYZE.

Logistic Regression Predicting Systolic Hypertension: We supplemented the linear regression analyses with a logistic regression model in which the continuous SBP measure was replaced by a dichotomous variable reflecting systolic hypertension clinical categories (0 = SBP $\leq$ 140, 1 = SBP > 140). The results of the logistic model predicting systolic hypertensive status (SBP > 140) were similar to those of the linear regression model though, as would be expected, tests of the parameter estimates were associated with less statistical power compared to the linear regression. In this model, none of the SES predictors were statistically significant. Among the biobehavioral variables, the statistically significant predictors were alcohol use (OR = 2.45 for heavy drinking versus no drinking, 95% CI = 1.76, 3.41); BMI (OR = 1.31 per 5 kg/m^2 increase, 95% CI = 1.23, 1.41); heart rate (OR = 1.15 per 10 beats/minute increase, 95% CI = 1.09, 1.20); (OR = 1.16 per 10 cm increase, 95% CI = 1.01, 1.39); and smoking (OR = 1.15 for smoking versus not smoking, 95% CI = 1.00, 1.33).

Path models: We used Mplus (v 3.01) to estimate out path models. Alcohol, exercise, smoking, respondent and parent education were specified as categories (as these are on the “y” side of some equations). We used the theta parameterization. Code for the primary model appears below. The original exercise variable in the Add Health database was found to be incorrectly coded and was therefore reversed in the call. We also allowed an indirect path from respondent education to SBP by way of household income and the biobehavioral variables. Associations were modeled as linear. We used the weighted least-squares with mean and variance adjustment (WLSMV) estimation procedure which allows the path coefficients to be interpreted in the original metric of the variables. Missing data were managed in path models using the full information maximum likelihood procedure (FIML). Estimates were also weighted using grand sample weights, and the school identification code was specified as a clustering variable.

As was the case with Chaix et al., we also found that the strong correlation between waist and BMI created estimation problems when both variables were included in the same model. Whereas Chaix et al. combined these two variables into a single “body shape” index, we chose to use only BMI in the primary model so that the indirect effect estimate would be more straightforward to interpret. We estimated a second model, in which we replaced BMI with the waist measurement.

<u>Mplus code</u>

```
Mplus VERSION 3.01
MUTHEN & MUTHEN
INPUT INSTRUCTIONS
  TITLE:PRIMARY MEDIATION MODEL
  DATA:
    FILE IS "Z:\xx\xx\xx\xx\xxxx.csv";
  VARIABLE: NAMES ARE
  AID  male  sbp  hr  bmi  waist
  drink  edclass  finstrn2
  smoke  exer   married
```

```
ownhome  race PSID  region GSWGT
hhinc  edclassp
edp2  ed2  cardmed
builtenv  age10
bmi32  hr72  waist100
hisp  black  asian  nvam  other
edp3  edp4  edp5
ed3  ed4  ed5
drink1  drink2  drink3  drink4;
 weight is gswgt;
cluster is psid;
  missing are all (-999);
 categorical are edclass edclassp drink
  smoke rexer;
USEVARIABLES  sbp  edclass edclassp
hhinc age10 hisp black asian
 nvam other male cardmed
 drink smoke
 hr  bmi rexer;
   define:
    rexer = exer;
    if (exer == 0) then rexer = 1;
    if (exer == 1) then rexer = 0;
ANALYSIS:
PARAMETERIZATION=THETA;
 TYPE=COMPLEX MISSING;
    ITERATIONS = 10000;
  CONVERGENCE = 0.00005;
 MODEL: sbp  on edclass  edclassp hhinc drink
 rexer smoke bmi hr
 age10 hisp black asian nvam other male cardmed;
edclass on age10 hisp black asian nvam other male cardmed;
   edclassp on  hisp black asian nvam other male age10 cardmed;
   hhinc on edclass hisp black asian nvam other male age10 cardmed;

   drink on hisp black asian nvam other male age10 cardmed
   edclass hhinc;
   rexer on  hisp black asian nvam other male age10 cardmed
   edclass hhinc;
   smoke on  hisp black asian nvam other male age10 cardmed
   edclass hhinc;
   bmi on hisp black asian nvam other male age10 cardmed
   edclass hhinc;
   hr on hisp black asian nvam other male age10 cardmed
   edclass hhinc;
  MODEL INDIRECT:
```

```
  sbp ind edclass;
  sbp ind hhinc;
output: sampstat standardized cint;
```

References

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Table S1: Medication data

Medication class	N	% of total
ACE Inhibitor	148	20.4
Beta-Blockade-Cardioselective	118	16.3
Combination Antihypertensive	73	10.1
Calcium Channel Blocker	64	8.8
Diuretic-Thiazide	50	6.9
Beta-Blockade-Non Cardioselective	49	6.8
Diuretic-Potassium Sparing	44	6.1
ACE II Inhibitor	39	5.4
Aldosterone Receptor Antagonist	33	4.6
Antiarrhythmic Group II	27	3.7
Diuretic-Loop	19	2.6
Antiarrhythmic Group I	15	2.1
Antiadrenergic-Centrally Acting	15	2.1
Antiarrhythmic Group IV	12	1.7
Diuretic-Carbonic Anhydrase Inhibitor	4	0.6
Antiarrhythmic Group V	4	0.6
Antiadrenergic-Peripherally Acting	4	0.6
Agents for Pulmonary Hypertension	2	0.3
Vasodilator	2	0.3
Renin Inhibitor	1	0.1
Antianginal Agent	1	0.1
Angent for Hypertensive Emergency	1	0.1
Total	725	100.0

Table S2. Indirect effects from education and income to SBP

Mediating pathway from respondent education	Indirect Effect (unstandardized)	95% CI
Education→BMI→SBP	-0.50	-0.66, -0.34
Education→Alcohol→SBP	0.13	0.06, 0.20
Education→Heart Rate→SBP	-0.20	-0.26, -0.14
Education→Exercise→SBP	0.08	-0.02, 0.18
Education→Smoking→SBP	-0.08	-0.32, 0.15
Total indirect effect of Education	-0.91	-1.19, -0.63
Direct effect of Education	0.32	-0.10, 0.73
Total effect of Education	-0.59	-0.91, -0.26

Income→BMI→SBP	-0.14	-0.32, 0.04
Income→Alcohol→SBP	0.12	0.04, 0.19
Income→Heart Rate→SBP	-0.07	-0.13, -0.004
Income→Exercise→SBP	0.01	-0.02, 0.04
Income→Smoking→SBP	-0.04	-0.13, 0.06
Total indirect effect of Income	-0.13	-0.29, 0.04
Direct effect of Income	-0.61	-1.03, -0.20
Total effect of Income	-0.74	-1.19, -0.29