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Socioeconomic status and health: education and income are independent and joint predictors of ambulatory blood pressure

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Abstract Epidemiological research suggests that different indicators of socioeconomic status (SES) such as income and education may have independent and/or interactive effects on health outcomes. In this study, we examined both simple and more complex associations (i.e., interactions) between different indicators of SES and ambulatory blood pressure (ABP) during daily life. Our sample consisted of 94 married couples who completed a one-day ABP protocol. Both income and education were independently related to systolic blood pressure and only income was significantly related to diastolic blood pressure. There were also statistical interactions such that individuals with high levels of both income and education evidenced the lowest ABP. Gender moderated these findings. Three-way interactions revealed that, in general, women appear to benefit from either indicator of SES, whereas men appear to benefit more from income. The findings are consistent with epidemiological research and suggest one important physiological mechanism by which income and education may have independent and interactive effects on health.

Keywords Income · Education · Gender effects · Socioeconomic status · Ambulatory blood pressure · Health

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Introduction

Despite the well-established, robust relationship between socioeconomic status (SES) and health, a clear understanding of the factors that contribute to and/or mitigate this relationship remains elusive (Matthews & Gallo, 2011), and identifying these factors continues to be a top public health priority (Department of Health and Human Services, 2010). Recent reviews and contributions to the SES-health literature suggest that this lack of clarity may, in part, be due to the fact that researchers often use SES indicators (e.g., income, education, occupation) interchangeably despite the fact that relationships between these indicators and health appear to differ in meaningful ways (Braveman et al., 2005). For example, there is evidence that SES indicators may be differentially related to the onset and progression of disease states (Herd et al., 2007) as well as show different patterns of associations with health risk (e.g., linear vs. nonlinear; Matthews & Gallo, 2011). Indicators of SES are also often only modestly correlated with one another (Geyer et al., 2006). Hence, though education and income are both indicators of SES, they are not identical constructs and each may have independent associations with health outcomes.

Besides their modest correlation, there is good conceptual reason to distinguish between indicators. For example, education appears to be a better index of psychosocial resources such as the ability to manage social systems (e.g., navigate the healthcare system), effectively regulate health behaviors, accrue social support, and develop a sense of personal control or agency (Matthews et al., 1989; Ross & Wu, 1995; Winkelby et al., 1992); whereas income is a more direct index of material resources. Hence, in as much as these indicators of SES index unique underlying risks for health, they are also likely to interact in their impact on health as both psychological and material resources can significantly affect death and disease through independent but interrelated processes (Adler et al., 1999; Johnston et al., 2009). Consistent with this reasoning, epidemiological research has found that the positive relationship between income and health can vary substantially by level of education (Schnittker, 2004). Specifically, those with more education have better health at all levels of income, and fewer income-based disparities exist among the well educated as compared to the less well educated.

Gender may also affect the relationship between social status and health outcomes. For example, social status is an index of one's standing in the social hierarchy and men and women appear to differ in their sensitivity to hierarchy formation and maintenance (Newton, 2009). Though gender is often treated as a control variable, some previous research has found gender differences in the relationship between SES and psychosocial and behavioral factors thought to contribute to SES-health disparities (Anderson & Armstead, 1995). Further, these interactions sometimes vary depending on which SES indicator is being assessed (e.g., education or income) (Marmot et al., 1997). For example, education may be a better predictor of SES disparities in self-reported health and psychosocial variables than is occupation for women, but not for men (Marmot et al., 1997). Another study of Swedish employees found that education and occupational rank predicted mortality for women and men, but income predicted mortality only for men (Torssander & Erikson, 2009), suggesting that personal income may protect men's health to a greater extent than women's. Additionally, Davey Smith et al. (1998) found that status-related health disparities (e.g., mortality) among working men were more closely associated with social class than education, suggesting that education may have a less direct effect on men's health than do material resources.

In the current study, we examined the relationship between income, education, and risk for cardiovascular disease, as indexed by ambulatory blood pressure (ABP) in daily life. An examination of links between SES and ABP is important because it could provide evidence for a biological mechanism linking SES to epidemiological health outcomes as ABP is a strong predictor of future cardiovascular risk (Conen & Bamberg, 2008; Pickering et al., 2006; Verdecchia, 2000; Zanstra & Johnston, 2011). Additionally, it has been proposed that the experience of low social status elicits sustained activation of stress-related autonomic responses, which promote atherogenesis (Steptoe et al., 2002). Monitoring individuals during daily experience is consistent with this conceptualization in that it allows for a comparison of overall blood pressure load as a result of the challenges encountered during daily life, as opposed to simply comparing one-time resting physiology or reactivity. Further, prior studies examining the relationship between SES and tonic blood pressure (BP) or one-time blood pressure reactivity have found an inverse relationship between SES and BP (see Starr & Deary, 2011 for a longitudinal analysis); however, this relationship is often moderated by intra- and inter-individual factors, such as hostility (Hawkley et al., 2011) or pessimism (Grewen et al., 2000), thought to increase day to day experiences of stress and contribute to disease.

Importantly, no studies to our knowledge have examined the associations among education and income and ABP or the extent to which gender may moderate these relationships. Instead, SES has typically been operationalized only as occupational prestige when examining ABP (e.g., Gallo et al., 2004; Steptoe et al., 2002), though there is evidence that other indicators of social status are also related to ABP (Landsbergis et al., 2003; McGrath et al., 2006). Based on prior epidemiological research, we expected that income and education would independently predict ABP, and that these indicators may also interact, such that high levels of one may protect against moderate or low levels of the other. Finally, we examined, in a preliminary fashion, whether income and education were differentially related to ABP in men and women, as prior work suggests that income may be a better predictor of men's health outcomes.

Methods

Participants

Participants were 94 healthy couples recruited from the community through newspaper ads and notices posted on campus. Participants were paid $75 (or awarded 2 credit hours in the participant pool for students) for their time. Because physiological measurements were taken, we excluded individuals who had medical conditions with a cardiovascular component (e.g., hypertension, diabetes), those who were taking cardiovascular prescription medications, and those with a diagnosed psychological condition for which they were being medically treated. Couples who had children currently living in the home were also excluded as part of the larger project (Bowen et al., 2012). Participants were all employed at least part-time, legally married and living together and ranged in age from 18 to 63 years with a mean age of 29.5. Most were White (83 %), college educated (62.4 %), attended church at least monthly or more (51 %) and had an annual household income over $40,000 per year (66 %). Average Body Mass Index for our sample was 25.61 kg/m^2 ($SD = 5.13$), with an average ambulatory systolic blood pressure (SBP) of 131.58 mm HG ($SD = 18.75$) and an average ambulatory diastolic blood pressure (DBP) of 77.91 mm HG ($SD = 12.89$).

Procedures

As part of the larger study protocol examining romantic couples and ABP, participants completed a one day ABP assessment, typically from 8 a.m. to 10 p.m. ($M = 14.01$ h, $SD = 0.97$) which included working hours and an evening at home with the spouse on the same day. A trained research assistant obtained consent from each participant, which included information on the nature of the study, potential risks, potential benefits, compensation and confidentiality. All participants were also reminded before starting the procedures that they would be free to withdraw at any time without penalty. Height and weight were assessed using a Health-o-Meter scale and participants were instructed to sit quietly while three baseline blood pressure readings were obtained, each taken one minute apart.

After filling out a demographic questionnaire, participants were fitted with the ambulatory blood pressure monitor by a trained research assistant and given detailed instructions on how to use it, including how to remove it at the end of the day. They were also given a palm pilot to record diary entries on basic control variables (e.g., posture) following each blood pressure reading and detailed instructions on how to use it. Participants were instructed to initiate a palm pilot ambulatory diary reading (ADR, see below) within 5 min of each cuff inflation and ambulatory readings were dropped from statistical analyses if participants failed to comply with this 5 min timeline. The average participant had fewer than one reading dropped from analysis due to noncompliance ($M = .78$, with a range from 0 to 7). Monitors were set to randomly obtain readings every 30 min from time of fitting until bedtime (approximately 10:00 p.m.). This random sampling procedure prevented participants from anticipating a reading and hence altering their activities. One reading was obtained before the participants left the lab to insure that the monitors were working properly and that participants understood how to use the palm pilots and how to correctly fill out the ADR. An appointment to return the equipment and to receive compensation the following day was set and participants were debriefed at the return appointment.

Measures

Income and education

Subjects were asked to report their annual household income and the number of years of education they had completed (see Table 1). As evident in Table 1, our measure of income significantly truncated the upper end of the range for this variable. Three participants did not report income and were thus deleted from relevant analyses. Income and education were not highly correlated in the current sample, $r\ (185) = .30$, $p > .05$.

Table 1 Response frequencies for income and education by gender

	Males		Females	
	Frequency	Percent	Frequency	Percent
Annual household income				
$3,000–$3,999	1	1.08	1	1.09
$7,000–$9,999	2	2.15	1	1.09
$10,000–$14,999	2	2.15	4	4.35
$15,000–$19,999	4	4.30	2	2.17
$20,000–$29,999	14	15.05	12	13.04
$30,000–$39,999	9	9.68	12	13.04
$40,000 or more	61	65.59	60	65.22
Education completed				
Partial high school	0	0	1	1.06
Completed high school	2	2.13	1	1.06
Partial college	39	41.49	27	28.72
Completed college	24	25.53	30	31.91
Partial graduate/ professional school	10	10.64	18	19.15
Completed graduate/ professional school	19	20.21	17	18.09

Three individuals were missing income data

Ambulatory blood pressure

The Oscar 2 (Suntech Medical Instruments, Raleigh, NC) was used to estimate ambulatory SBP and ambulatory diastolic blood pressure (DBP). The Oscar was developed to meet the reliability and validity standards of the British Hypertension Society Protocol (Goodwin et al., 2007). The cuff was worn under the participants' clothing, and only a small control box (approximately 5.0 × 3.5 × 1.5 inches) attached to the participant's belt was partially exposed. Outliers associated with artifactual readings were identified using the criteria by Marler et al. (1988). These included: (a) SBP < 70 mmHg or >250 mmHg, (b) DBP < 45 mmHg or > 150 mmHg, and (c) SBP/DBP < [1.065 + (.00125 × DBP)] or >3.0.

Control variables

Participants were given a portable palm pilot device and instructed to complete a series of programmed questions following each ambulatory cardiovascular assessment. These programmed questions were designed to be easy to complete (about 2–3 min) in order to maximize cooperation and contained information on basic variables that might influence ABP (Kamarck et al., 1998). These included posture (lying down, sitting, standing), activity level (1 = no activity, 4 = strenuous activity), location (work, home, other), talking (no, yes), temperature (too cold, comfortable, too hot), prior exercise (no, yes), and prior consumption of nicotine, caffeine, alcohol or a meal (no, yes). Though we did not exclude participants who used tobacco products, 94 % of our sample were nonusers.

Consistent with prior research, preliminary analyses revealed that age, gender, body mass, posture, temperature, activity level, prior alcohol, and prior exercise were independent predictors of higher ambulatory SBP (p's $< .05$). In addition, age, gender, body mass, posture, activity level, and a prior meal independently predicted ambulatory DBP (p's $< .05$). Nicotine consumption was not significantly related to either SBP or DBP (p's $> .05$). Consistent with prior work, these factors along with time (i.e., first reading, second reading) were thus statistically controlled in all analyses involving ABP (Kamarck et al., 1998).

Analyses

We utilized Proc Mixed (SAS Institute) in order to examine ABP during daily life, which allows one to more accurately model the covariance structure for repeated measures factors. This method also allowed us to account for statistical non-independence in our sample of married couples. In the present study, we modeled the covariance structure for the two repeated measures factors of dyad (i.e., husband, wife) and measurement occasion (i.e., reading number) using the direct (Kronecker) product. This was modeled using the "type = un@ar(1)" option which is a within-subjects covariance profile containing the product of the two separate covariance matrices (Galecki, 1994). As recommended by Campbell and Kashy (2002), we used the Satterthwaite approximation to determine the appropriate degrees of freedom. All analyses were performed using continuous scores for predictors (income, education). We dichotomize education in follow up analyses simply as a method to depict our pattern of findings, as suggested by Aiken and West (1991).

Results

In our main analyses, we first entered both income and education together into the model (Model 1; Table 2). We found that both income and education were significantly and independently associated with lower SBP. Income was also associated with lower DBP; however, education was not. These results are consistent with prior work in that they suggest that education and income are not redundant constructs (Braveman et al., 2005).

We next examined if income and education interacted to predict ABP (Model 2, Table 2). The statistical interaction

Table 2 Results of stepped examination of income, education and gender on ABP

Model and predictors	Dependent variables	
	SBP	DBP
Model 1		
Income	−1.6***	−0.6**
Education	−1.2**	−0.2 (ns)
Model 2		
Income	−1.4***	−0.5*
Education	−1.2***	−0.2 (ns)
Income × education	0.5*	0.4**
Model 3		
Income	−1.8***	−0.6**
Gender	−9.8***	−1.7***
Income × gender	1.7**	0.6 (ns)
Model 4		
Education	−1.5***	−0.4 (ns)
Gender	−10.2***	−2.0***
Education × gender	−0.2 (ns)	−0.9*
Model 5		
Income	−1.9***	−0.8**
Education	−0.9**	−0.1 (ns)
Gender	−10.1***	−2.0***
Income × education	0.0 (ns)	0.2 (ns)
Gender × income	2.2**	0.9 (ns)
Gender × education	−0.8 (ns)	−1.0*
3-way (Inc × Edu × Gen)	1.0*	0.8**

Values shown are unstandardized parameter estimates. All models also included standard control variables (e.g., BMI) as noted in the Methods section

ns nonsignificant

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

between income and education was significant for both SBP (see Fig. 1, Panel A and B, respectively). We dichotomized education in order to examine the simple effects of income in this interaction; greater income was significantly associated with lower blood pressure (i.e., health protective) for those who reported completing partial college or less ($b = -2.6$ and $b = -1.3$ respectively for SBP and DBP, both $p < .001$), but not for those with higher education ($p > .1$ and $p > .9$. respectively).

We also examined if gender moderated links between these indicators of SES and ABP (Models 3 and 4, Table 2). The negative association between income and SBP was significantly moderated by gender (Fig. 2, Panel A) such that the slope of the inverse relationship was steeper for men than for women ($b = -2.7$, $p < .001$ and $b = -.97$, $p < .05$, respectively). The negative association between education and DBP was also moderated by gender (Fig. 2, Panel B), such that the slope of the inverse

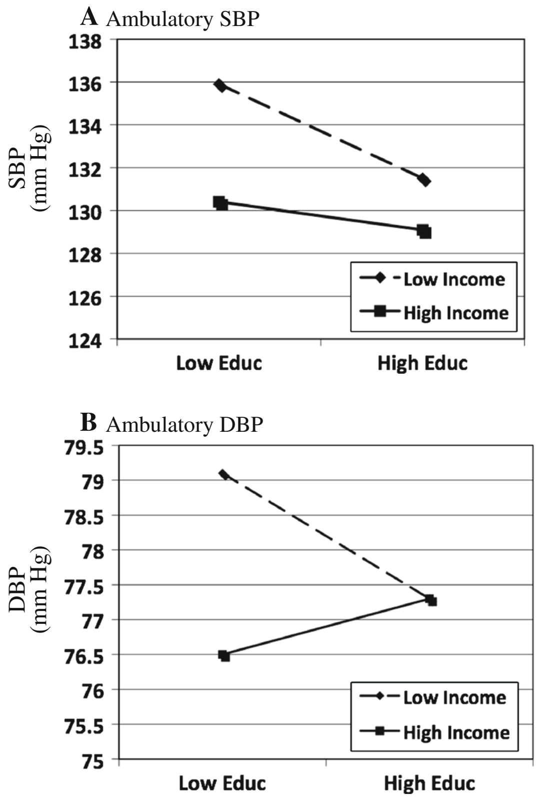

Fig. 1 Education and income interact to predict ABP. Higher levels of education are more protective for individuals with lower incomes. Similarly, higher levels of income are more protective for individuals with less education

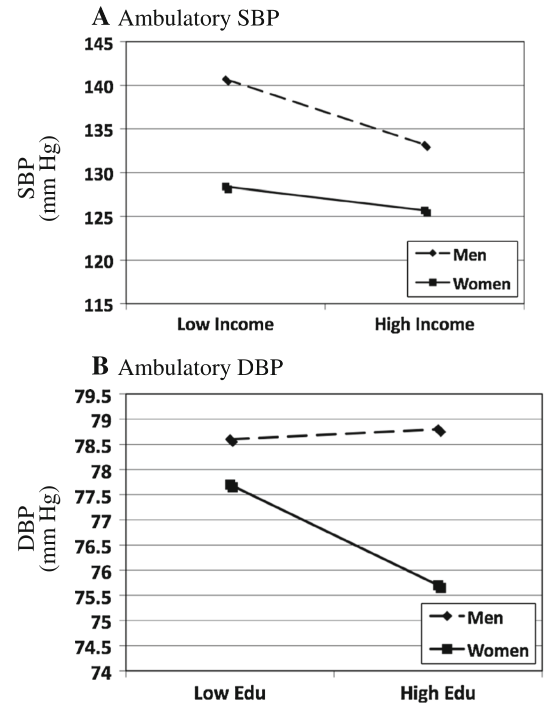

Fig. 2 Gender moderates the main effects of income with SBP and education with DBP such that income and SBP are more closely associated for men and education is negatively associated with DBP for women but not men

relationship was only significant for women ($b = -.76, p < .05$ and $b = .03$, $p > .90$ for women and men respectively).

Lastly, gender also moderated the interaction between education and income, resulting in three-way interactions (gender × education × income) for both SBP and DBP (Model 5, Table 2). We then tested the education × income interactions for men and women separately and found that the interaction was associated with lower SBP and DBP in women ($b = .54$, $p < .05$ and $b = .56$, $p < .01$ respectively), such that education appears to have a greater effect at low income than high income (see Figs. 3, Panel B, 4, Panel B, respectively). Neither simple two-way interaction was significant for men (both $p > .30$).

Discussion

In studies of health disparities, indicators of SES (e.g., income, education, occupation) are often used interchangeably or combined to form a single factor. However, evidence suggests that these indicators may be differentially and independently associated with health (Elo & Preston, 1996; Herd et al., 2007; Sorlie et al., 1995). The

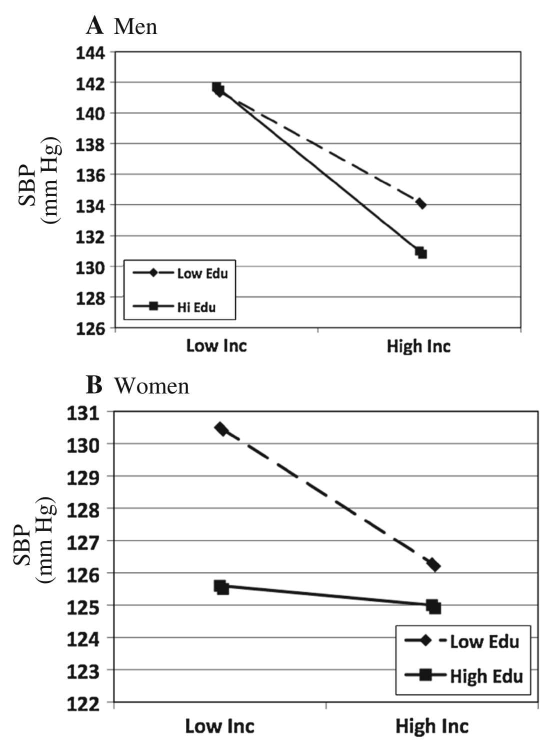

Fig. 3 Gender moderates the interaction between income and education on SBP

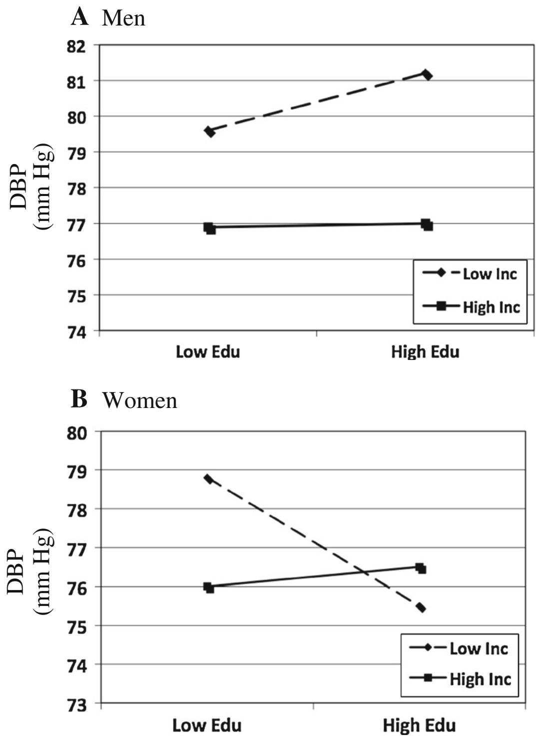

Fig. 4 Gender moderates the interaction between income and education on DBP

current study provides support for the hypothesis that SES indicators are not interchangeable in terms of health risk, as education and income had independent associations with ABP. Importantly, these links were moderated by gender. Only men's SBP was significantly associated with income and only women's DBP was significantly associated with education. These findings are consistent with some past work suggesting that income may protect men's health to a greater degree than women's health (Torssander & Erikson, 2009).

Our results are also consistent with large-scale epidemiological research showing that SES indicators may interact to protect health (Schnittker, 2004). Our work extends this literature specifically to cardiovascular disease using an objective measurement of risk (ABP) in well-controlled analyses, suggesting one physiological mechanism linking income and education both jointly and independently to health.

Specifically, we find that higher levels of education are associated with lower levels of blood pressure in daily life otherwise found at lower levels of income, and that higher levels of income are associated with lower levels of blood pressure at lower levels of education. If supported by additional research, these results suggest the possibility that increasing education in low income populations may help to reduce the increased risk of cardiovascular disease associated with low income. However, no such causal conclusions can be drawn from the current study.

Gender also moderated the interaction between education and income on health. These three-way interactions revealed that lower blood pressure in women was associated with both indicators of SES, and that higher education was associated with lower blood pressure within lower income women. However, lower blood pressure in men was mainly attributable to increased income rather than an interaction between these two indicators of SES, and education was not associated with lower blood pressure within lower income men (Fig. 4, Panel A). This finding is consistent with prior larger-scale work on SES indicators and health (Davey Smith et al., 1998). In short, there is little evidence that education is independently associated with lower ABP for men over and above the inverse association between ABP and income. However, both education and income are independently and inversely associated with ABP in women, and education may offset the risk for high blood pressure associated with low income.

Hence, men's cardiovascular risk appears to be more closely related to income and women's to education, though income still confers independent risk for women. These gender differences may suggest that SES indicators differentially influence overall social status and/or perceived status for women and men, as perceived social status can influence health above and beyond material resources (Adler, 2009; Adler et al., 1994). Alternatively, education may be more closely associated with freely conferred social status (i.e., prestige) (Henrich & Gil-White, 2001) in women but not men (e.g., men may be more likely to confer status based on earnings). Such conferred status may affect health by reducing dominant strivings for status and effortful attempts to influence or control others, a status attainment strategy which has been associated with greater cardiovascular reactivity (Smith & Brown, 1991; Smith et al., 1996, 2012). Additionally, these gender differences may indicate that resources related to coping (i.e., education) most effectively buffer stress for women, whereas financial resources (i.e., income) most effectively buffer stress for men. Lastly, perhaps education is more protective for women because it is most closely related to social integration and support (Umberson & Montez, 2010), as there is evidence that affiliative concerns such as social connection may be more closely related to women's health than to men's health (Kiecolt-Glaser & Newton, 2001; Smith et al., 1998, 2011). Clearly, there could be many different interpretations of our findings, and the psychobiological processes underlying this gender difference warrant further research.

Limitations and conclusions

The current findings may not generalize beyond the largely Caucasian and middle and upper-middle-class population studied here, and there is reason to believe that findings may differ by ethnicity (Steffen, 2006). These results may also not generalize to younger adult or adolescent populations or to unmarried or divorced men and women. Additionally, the measure of income was significantly truncated. However, this restriction of range is most likely to weaken our ability to find the differences reported here (not artificially inflate them). Additionally, although this sample does not allow us to generalize our findings to those lower in the SES spectrum, there is significant data to suggest a monotonous, linear link between SES and health (Adler et al., 1994). Lastly, the current study was a cross-sectional design, and therefore no causal conclusions can be drawn. Though other third variables may account for these relationships, it seems unlikely that higher ABP that is not confounded with the diagnosis of a chronic disease would lead to lower income or education.

These limitations notwithstanding, income and education were independently and interactively associated with ABP, and these associations varied by gender. ABP is a strong predictor of future cardiovascular risk (Conen & Bamberg, 2008; Pickering et al., 2006; Verdecchia, 2000), and these results extend prior work on disease states to physiological disease processes. Further, linking SES to ABP in daily life is consistent with theory and suggestions that differences in everyday interactions may account for a significant portion of the graded relationship between status and health (Adler, 2009; Kamarck et al., 2012; Smith et al., 2012). These results support prior research that SES indicators are not interchangeable, may interact, and may be differentially important for men and women. Further examination of separate and interactive effects of SES indicators may help clarify the effects of various aspects of social status on disease processes and health, and, over time, may suggest policy implications in the effort to ameliorate SES-related health disparities.

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