Developmental, Gender, and Ethnic Group Differences in Moods and Ambulatory Blood Pressure in Adolescents

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ABSTRACT

Background: *Adolescence is characterized by profound changes in physical, psychological, and social functioning thought to be accompanied by intense and varying moods.* ***Purpose:*** *Within a psychophysiological framework, this study examined the prevalence of 12 self-reported mood states of adolescents; investigated associations between specific mood states and ambulatory blood pressure readings; and explored effects of interactions among moods, gender, ethnic group, and maturation on ambulatory blood pressures.* ***Methods:*** *The sample included 371 African American, European American, and Hispanic American adolescents 11 to 16 years old. Systolic (SBP) and diastolic (DBP) blood pressures were measured every 30 min with an ambulatory monitor and were synchronized with electronic activity monitoring and moods self-recorded during waking hours in a checklist diary.* ***Results:*** *Moods differed significantly by gender, ethnic group, and maturation. Controlling for height, maturation, gender, ethnic group, mother's education, position, location, activity, other moods, and interactions of moods with other variables in a multilevel, random coefficients regression model, both positive and negative mood states were associated with higher levels of SBP and DBP; being relaxed or bored, or having a feeling of accomplishing things were associated with lower SBP and DBP. There were significant interaction effects of moods with physical maturity, gender, and ethnic group on ambulatory SBP and DBP.* ***Conclusions:*** *Further study of the modifying effects of gender, ethnic group, and stage of development on reports of moods, and their associations with cardiovascular responses is recommended.*

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INTRODUCTION

Psychosocial and physiological phenomena interact to increase the risk of adverse cardiovascular outcomes; however, the pathways through which they act are not fully understood. A psychophysiological model that links moment-to-moment changes in cardiovascular indicators such as blood pressure and heart rate with long-term cardiovascular outcomes was proposed by Sloan et al. (1). In this model, physical factors (aging and neuropathy), psychosocial and emotional factors (depression, anxiety, anger, and work stress), and health behaviors (specifically, physical deconditioning) may operate to decrease autonomic control, leading to an increase in blood pressure variability in response to challenge. Chronic increases in blood pressure variability over the long term may increase the risk of cardiovascular diseases through endothelial damage, atherosclerosis, plaque disruption, and thrombosis. On the basis of this framework, it is purported that cardiac control, which is mediated autonomically, serves to buffer blood pressure fluctuations, especially in response to challenge. Those who are less able to buffer blood pressure responses to challenge are presumably at higher risk for adverse cardiovascular outcomes.

The design of this study is consistent with this theoretical framework. It examined frequent, intermittent assessments of blood pressures and moods of adolescents under natural conditions. This, combined with a means to assess the respondents' physical activity and psychosocial experiences, enabled an examination of individual and group differences in cardiovascular responses to challenges encountered during daily activities.

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We conceptualized emotions as processes that involve cognitions, feelings, physiological responses, impulses, and behaviors (2). *Moods*, as defined for the purposes of this study, are the self-perceived feeling states that are part of complex emotional processes. Positive and negative moods compose the major dimensions of affect, with degree of arousal another important aspect (3,4). Within these general dimensions of affective states more detailed structures have been derived and have led to alternative inventories and response formats for self-rated mood states.

Ambulatory methods provide a means to study blood pressure variability that occurs during the course of daily activities and to link specific blood pressure readings to self-rated mood states. Ambulatory blood pressure has been studied extensively in adult populations, and moods have been linked with these measurements in a number of samples. There is evidence to support the idea that it is the degree of emotional arousal or engagement, rather than the negative aspect of emotions, that is associated with increases in blood pressure (5). There is considerable evidence from studies of adults that negative as well as positive moods are associated with elevations in blood pressure (5–8). Moods that reflect disengagement or low levels of arousal, such as "tired," "sleepy," and "bored," have been linked with lower levels of cardiovascular response in previous studies (5,6,8–10). In one recent study, a more complex pattern was reported: Cardiovascular responses did not significantly covary with happiness, but happiness did neutralize diastolic blood pressure (DBP) responses to negative moods (9).

Previous studies vary in sample composition, data collection methods, and approaches to statistical analysis. Clinical samples of hypertensive patients have been studied (7), as well as specific occupational groups thought to have stressful working conditions (9–12), and healthy adults of various ages (5,6,8,13–16). Several negative aspects of moods such as anger are almost always included in diaries, whereas positive moods either are not included or may represent a small proportion of the mood inventory. Previous studies are heterogeneous in the extent and methods used to control for time-dependent variables that could confound the relationship between moods and ambulatory blood pressure. Location or situation (home, work, school, etc.), position (reclining, sitting, standing) and physical activity level are frequently assessed at the time of each blood pressure measurement. In one study, none of these covariates was controlled (9). In most previous studies, data on these variables were self-reported in the same diary in which moods were recorded. Alternatively, physical activity can be measured more objectively by observation (17) or with an actigraph, but these approaches are relatively uncommon. To further complicate comparisons among studies, the covariation of activity appears to be sample dependent. Younger hypertensive study participants exhibited stronger associations of electronically measured physical activity with ambulatory blood pressure and heart rate than older hypertensive individuals (18), and very little association was observed in healthy, older participants (19). Earlier studies of adults and adolescents were limited by the statistical approaches that were used, as Schwartz et al. (6) noted. More recently, mixed models have been appropriately applied to ambulatory blood pressure and other momentary assessment data (20). In summary, there is quite an extensive body of literature on the relations between moods and ambulatory blood pressure responses in adults. Elevations in ambulatory blood pressure have been associated with negative as well as positive moods that reflect a high level of engagement. There has been some consistency of findings across studies in spite of the heterogeneous samples and methods.

Adolescence is a stage of development characterized by profound changes in physical, psychological, and social functioning, thought to be accompanied by intense and labile emotions. However, empirical studies of affective states do not indicate that puberty has a profound effect on the structure of mood during adolescence (21). Furthermore, only a few previous studies have linked emotions and moods of adolescents to their ambulatory blood pressure readings. In correlational analyses of a small selected sample of adolescents, reports of negative moods were associated with increases in ambulatory systolic blood pressure (SBP); positive moods were not correlated with ambulatory SBP or DBP (22). This study and those of Ewart and Kolodner (17,23) found that blood pressure responses to tasks in a controlled setting were positively related to ambulatory levels of blood pressure. In all instances, the samples included African American and White adolescents and were focused on those at the upper end of the blood pressure screening distribution. Ages of adolescents ranged from 13 to 18 years. Investigations that include younger adolescents are needed so that researchers could simultaneously address variations in blood pressure attributable to physical factors (growth and sexual maturation) as well as emotional factors.

Prior studies that have systematically compared demographic subgroups are also relevant to this investigation, in which we compared groups of adolescents based on gender, ethnic group, and physical maturation. In a clinical sample, ambulatory DBP for men was greatest at times that anger was reported but, for women, DBP elevation was greatest at times of reported anxiety (7). In a sample of normotensive men and women on 2 working days and 1 nonworking day, there were complex associations among gender, parental roles, moods, stressful events, and perceived levels of stress. Demographic and situational factors were associated with gender differences in DBP, but moods did not mediate the effects of gender on DBP levels (16). Another study found significant effects of emotional arousal on heart rate but not blood pressure; this effect applied to White but not African American participants and was significant only during periods of low negative affect (14). In a comparison of Filipino American and Caucasian nurses and nurses' aides, interactions among negative moods, ethnicity, setting, and posture were significantly associated with DBP variability. Caucasian nurses had greater increases in DBP when they reported anxiety than did Filipino American nurses (10). Thus, previous studies of adults indicate that interaction effects among demographic subgroups are common and complex. We explored similar interactions in this study of adolescents.

Measurement of blood pressure during adolescence and the investigation of gender and ethnic group differences in covariation of moods with blood pressure are complicated because this is a period of rapid growth, body size is closely related to blood pressure, and girls reach adult height and puberty earlier than boys. Furthermore, African American children mature, on average, at an earlier age, and Hispanic adolescents tend to be shorter than Anglo (European American or Caucasian) or African American adolescents. No previous studies of ambulatory adolescent blood pressure have explicitly investigated differences in maturation along with ethnic group and gender differences.

The Heartfelt Study extended previous work on emotional factors and cardiovascular health of adolescents by addressing growth and maturation (24–27). It further extended previous studies of adolescents by focusing on a general population of adolescents rather than those at the highest levels of blood pressure. We previously reported that blood pressure reactivity to talking about anger-provoking and neutral situations predicted ambulatory blood pressure in two multi- ethnic samples of adolescents. Using a mixed-models approach, between-subjects variables such as body size, sexual maturation, and ethnic group were controlled as well as the time-dependent covariates of position, location, and activity level (24,25). In this report we further extend analysis of the Heartfelt Study data by examining the influence of state measures of moods on ambulatory blood pressure in this multiethnic adolescent sample. The aims were to (a) estimate the prevalence of mood states in a multiethnic sample of adolescents; (b) test for differences in the prevalence of 12 moods by ethnic group, gender, and maturation; (c) investigate the relations between mood states and ambulatory blood pressure measured during the course of daily activities; and (d) explore effects on ambulatory blood pressure of interactions of the mood variables with gender, ethnic group, and physical maturation.

METHOD

Setting and Sampling Plan

The target population was 11- to 16-year-old African American, European American, and Hispanic American adolescents residing in Houston, a large metropolitan city in southeast Texas. Houston's population of nearly 2 million people is diverse; 25% identify themselves as African American, and 37% report a Hispanic, primarily Mexican American, background (28). The sample was accessed through middle and high schools in the Houston Independent School District, which has ethnically diverse student bodies. Principals of middle and high schools in the district were asked to volunteer by the district administrator for student health. From among schools that volunteered, we selected two high schools and one middle school that had ethnic–racial diversity in the three population groups that were targeted and were geographically accessible to the university. Total enrollment in these three schools at the beginning of the study was 1,641 in the middle school and 1,990 in the high schools. The distribution of African American, European American, and Hispanic American adolescents was 31%, 32%, and 30% of the middle school, and 31%, 23%, and 38% of the high school student bodies, respectively.

Parental consent materials were distributed to students, and information about the study was presented on a schoolwide basis in large assemblies, during homeroom periods or in physical education classes. A stratified, quota sampling plan was used to select participants from among those who volunteered. Strata were defined by chronological age, ethnic group, and sex; if more than the quota for each stratum volunteered, participants were selected randomly. The sampling plan was designed to include approximately equal numbers of each gender and ethnic–racial group. Because maturation affects blood pressure and girls begin puberty about 2 years earlier than boys, we made an attempt to oversample younger girls and older boys. This plan was devised to ensure that the male and female groups would overlap in terms of biologic, rather than chronological, age.

The Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston approved the study. Because adolescents were recruited in general assemblies or in compulsory classes, such as physical education, certain groups were not systematically excluded on the basis of enrollment in particular courses. Those who volunteered to participate were required to have written consent from a parent or guardian. Students who completed all components of the protocol, including the 24-hr blood pressure monitoring, were reimbursed $30.

There were 406 participants in the study. Twenty-four were dropped from the study because of incomplete data for one or more of the following reasons: 11 had missing or incomplete actigraph data, 5 had missing diaries, 9 had incomplete ambulatory blood pressure data, and 2 were participant-initiated withdrawals. Eleven participants with complete data classified their ethnic group as "other" and were dropped from this analysis. The sample for analysis thus consisted of 371 adolescents, 11 to 16 years old. There were more girls (53.5%) than boys. A higher proportion of the respondents was African American (37.5%) compared with the proportions of Hispanic American (31.4%) and European Americans (31.1%). A broad range of socioeconomic status was represented in the sample. Mother's education ranged from none to graduate or professional training. Almost half (45.5%) of participants' mothers had 12 years of education or less.

Procedures and Instruments for Data Collection

Ambulatory blood pressure and activity monitoring. Blood pressure was monitored for 24 hr on a school day using the SpaceLabs ambulatory equipment (Model 90207; SpaceLabs, Inc., Redlands, WA). Activity and sleep–wake intervals were monitored with the Motionlogger actigraph (Model 20.000; Ambulatory Monitoring Inc., Ardsley, NY). Each participant was fitted with an appropriately sized cuff and the Motionlogger on the nondominant arm and wrist. The ambulatory blood pressure monitor, an oscillometric device, was calibrated against a mercury sphygmomanometer, and the blood pressure and activ-

ity monitors were synchronized. Participants were instructed to wear the monitors throughout the 24-hr period except during bathing or swimming and to keep their arms still when the cuff inflated every 30 min. Participants were instructed how to remove and then replace the monitor if necessary and were given a 24-hr pager number if they encountered any problems with monitors. If a reading was missed, usually because of excessive arm movement or motor vehicle vibration, a repeat measurement was attempted automatically 2 min later.

Ambulatory blood pressure readings during waking hours are included in this analysis. If the participant failed to complete a page of the diary during these hours, that observation of blood pressure was considered missing. Five actigraph readings immediately preceding a blood pressure recording were averaged and used to control for activity at the time of each measurement.

Diary. After each blood pressure measurement during waking hours, the participant noted his or her location (home, school, other), position (standing, sitting, reclining), and moods (angry, excited, happy, stressed, accomplishing things, bored, interested, rushed, irritable, sad, neutral, relaxed) in a checklist diary. Each participant was instructed individually in use of the diary and was given an opportunity to practice. The format and content of the diary were adapted from those used in previous studies (6,29). Electronic diaries were considered but abandoned during the pilot phase of the research because of the likelihood that they would be lost or stolen. A pocket-sized spiral notebook, with a separate page for the participant to complete after each blood pressure measurement, was pilot tested and found to be completely adequate, except for the fact that it was not possible to detect if the student filled out the diary at the time of each blood pressure measurement or if some entries were made retrospectively to comply with the study requirements. After the pilot phase of the project, the response format for moods was changed from a 5-point scale of intensity to a yes–no checklist. This was done to reduce the response burden for the participants and minimize missing diary information.

Physical examination. Height, weight, and sexual maturity using the criteria of Tanner (30) were measured during a physical examination by nurse practitioners trained in the research protocol. The sexual maturity variables with the greatest variability in this age range are genital development stage in boys and breast development stage in girls (27). To simplify the statistical modeling of sexual maturation, Stages 1, 2, and 3 were grouped together (less mature), as were Stages 4 and 5 (more mature) (27). About two thirds of the sample were in Stages 4 and 5 (104 boys and 130 girls), as would be expected given the age range. Elsewhere, sexual maturity has been shown to affect resting SBP in the sample, independent of body size and chronological age (26); hence it is a potentially important correlate of ambulatory blood pressures.

Two resting blood pressures were taken with a mercury sphygmomanometer (Baumanometer–300; W.A. Baum Co. Inc., Copiage, NY), stethoscope, and an appropriately sized cuff after the participant had been sitting quietly for 5 min. These two readings were averaged.

Sociodemographic variables. Ethnic group was self-identified. A parent or guardian was interviewed by phone to obtain data on education and occupation of adult members of the household. Data for mother's education were most complete and were used as an indicator of socioeconomic status of the participant. We dichotomized this variable for analysis using an approach similar to one used in a recent study of blood pressure reactivity in adolescents (31). Those with mothers who had 12 years of education or less were compared to those whose mothers had more than 12 years of education.

Statistical Analysis

The prevalence of each mood state is presented as a percentage of (a) individuals reporting each mood at least once, (b) all mood states reported for the sample, and (c) moods reported per individual (see Table 1). To describe differences among gender, ethnic, and maturation groups in prevalence of each of the 12 mood states, we estimated the odds ratios using generalized estimation equations method (GENMOD procedure; SAS Institute, Cary, NC) and are presented in Table 2. The generalized estimation equations method allows comparisons among different groups for a nonnormal outcome with repeated observations. It does not require that the number of observations on each participant be identical. Next, for descriptive purposes, means and standard deviations of ambulatory and resting blood pressures are presented in Table 3.

Finally, we used a multilevel, random coefficients regression model for repeated measures data described by Laird and Ware (32) for testing relations between ambulatory blood pressure and several independent variables (MIXED procedure; SAS Institute, Cary, NC). Separate analyses were conducted for SBP (see Table 4) and DBP (see Table 5). A two-stage model with each participant as the unit of analysis and each repeated measurement of ambulatory blood pressure as the subunit provided a means to deal with an unbalanced data set and lack of statistical independence of multiple measurements on the same individual. At the individual level of analysis, the independent variables were gender, ethnic group, and maturation. At the within-subject level of analysis, 12 moods were tested as independent variables in relation to ambulatory SBP and DBP. To control for confounding at the individual level of analysis, height and socioeconomic status were entered. To control for confounding at the within-subject level, time-varying covariates for each ambulatory blood pressure measurement were activity, position, and location. We used Aikaike's information criterion to compare the autoregressive correlation structure with the compound symmetry structure and with the simple variance component structure. The best fit was achieved using autoregressive correlation structure of degree one. This structure is applicable to ambulatory blood pressure data because measurements on an individual at adjacent time intervals are likely to be more highly correlated than those taken at time intervals further apart. The fit of alternative models with and without

interaction terms was assessed with Aikaike's information criterion.

RESULTS

Prevalence of Moods

Each mood was reported by 65% or more of the respondents at least once (see Table 1). An exception was "sad," which was reported by 43.1% of the respondents. An examination of the percentage of all mood reports for the sample (Table 1, column 2, denominator is all mood reports) and of individuals (Table 1, column 3, denominator is the number of mood reports for each individual) revealed a different pattern. Feeling relaxed, neutral, or happy were the most prevalent moods (*Mdn* percentage per individual = 49%–68%), followed by accomplishing things, bored, and interested (*Mdn* = 22%–28%). Much less prevalent were reports of being excited, stressed, or rushed (*Mdn* = 10%–12%). Reports of feeling irritable, angry, or sad were reported rarely (*Mdn* = 0%–6.5%). The interquartile ranges for the prevalence of moods revealed a great deal of variability among individuals around the medians reported in Table 1.

The odds of reporting each mood by gender, ethnic group, and maturity are reported in Table 2. Male adolescents compared with female were less likely to report accomplishing things, feeling sad, or feeling rushed. African American adolescents were less likely to report feeling neutral, bored, interested, stressed, or rushed than were European American adolescents. Hispanic American adolescents were less likely to report feeling interested than European American adolescents. This was the only significant difference between these two groups. African American respondents were less likely to report feeling rushed or sad compared with Hispanic American respondents. Less mature compared with more mature adolescents were less likely to report being stressed, rushed, irritable, sad, or accomplishing things, and they were more likely to report feeling excited.

TABLE 1
Prevalence of Mood States Among Adolescents, 11 to 16 Years Old, in Houston, Texas

Mood	*% of Individuals Reporting at Least Once*	*% of All Mood States Reported*[a]	*Median % per Individual*[b]	*Interquartile Range*[b]
Relaxed	94.8	61.0	67.7	40.0, 59.0
Happy	94.5	49.7	49.2	27.7, 80.0
Bored	90.8	29.2	25.9	10.0, 43.8
Accomplishing things	87.9	32.3	27.6	8.7, 51.6
Interested	87.1	28.5	22.3	6.9, 44.4
Neutral	86.9	50.6	57.7	17.6, 83.9
Excited	82.0	20.0	12.3	3.3, 28.6
Stressed	78.2	19.1	10.9	2.9, 27.3
Rushed	75.5	16.1	10.0	2.8, 24.1
Irritable	67.4	13.4	6.5	0, 18.5
Angry	65.3	8.1	3.6	0, 10.0
Sad	43.1	7.1	0.0	0, 6.5

Note. $N = 371$.
[a]Denominator is all mood reports. [b]Denominator for each individual is the number of mood reports for that individual.

TABLE 2
Odds Ratios for Reporting Each Mood by Gender, Ethnic Group, and Sexual Maturation of Adolescents in Houston, Texas

Mood	*Boys/ Girls*	*AA/EA*	*HA/EA*	*AA/HA*	*Less Mature/ More Mature*
Relaxed	0.81	1.03	1.05	0.98	0.87
Neutral	0.77	0.60**	0.80	0.75	0.84
Happy	0.81	1.07	0.94	1.14	1.15
Accomplishing things	0.66***	0.81	0.74	1.10	0.69**
Bored	0.86	0.74*	0.80	0.92	0.85
Interested	0.86	0.69*	0.72*	0.96	0.79
Excited	0.83	1.19	1.24	0.96	1.53*
Stressed	0.80	0.66*	0.70	0.95	0.54****
Rushed	0.67**	0.63*	0.95	0.67*	0.67****
Irritable	0.85	0.78	0.73	1.08	0.51****
Angry	0.93	1.06	1.08	0.98	1.05
Sad	0.45**	0.59	1.18	0.50*	0.31****

Note. $N = 371$. AA = African American; EA = European American; HA = Hispanic American.
$^{*}p \le .05$. $^{**}p \le .01$. $^{***}p \le .001$. $^{****}p \le .0001$.

Descriptive Statistics for Ambulatory and Resting Blood Pressure

Descriptive statistics for ambulatory blood pressure readings while awake, and resting sphygmomanometer readings taken while sitting, are presented in Table 3. Resting blood pressure readings were lower than daytime ambulatory readings in every subgroup. SBP levels for male adolescents were higher than those for female in all ethnic groups. Within each gender group, African American adolescents had slightly higher mean SBP and DBP than the other two groups; resting SBP was an exception to this pattern.

Mood States and Ambulatory Blood Pressure Levels

Mixed-effects analysis was applied with ambulatory SBP and DBP, analyzed separately, as the dependent variables (n = 8,428 blood pressures). With all independent variables in the model, the sample size was reduced to 307 individuals because of missing data on one or more variables. First, the associations of each mood with SBP and DBP were tested. Second, the analysis was expanded to include independent variables at the individual level of analysis (gender, ethnic group, maturation), individual characteristics to control for confounding (height and mother's education), time-varying covariates for each ambulatory blood pressure measurement (activity, position, and location), and all other moods. This is referred to as the *full model*. Third, all possible interactions of gender, ethnic group, and maturation, and interactions of these variables with each mood,

TABLE 3
Descriptive Statistics Ambulatory Awake and Resting Blood Pressures for Adolescents by Gender and Ethnic Group in Houston, Texas

	African American[a]		*Hispanic American*[b]		*European American*[c]	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Systolic blood pressure						
Boys						
Ambulatory	123.7	10.4	123.1	9.9	122.9	9.9
Resting	107.5	10.1	108.7	12.1	110.6	13.2
Girls						
Ambulatory	120.4	9.9	119.5	9.8	118.7	9.7
Resting	106.1	8.1	103.3	9.3	103.1	8.7
Diastolic blood pressure						
Boys						
Ambulatory	73.6	9.3	71.6	8.9	72.2	9.5
Resting	63.4	9.1	60.1	11.4	62.3	11.9
Girls						
Ambulatory	73.1	9.0	72.5	8.6	72.2	8.5
Resting	63.9	11.2	61.4	8.0	60.8	8.5

Note. $N = 371$. Ambulatory values were obtained using a SpaceLabs monitor. Resting values were obtained using a sphygmomanometer.
[a]$n = 139$. [b]$n = 117$. [c]$n = 115$.

were tested in separate mixed models. From these mixed models, significant interactions were identified and added to the full models. These models for SBP and DBP were then trimmed to include only the main effects and significant interaction terms, resulting in the final models.

The fit of the model for both SBP and DBP was significantly improved with the interaction terms. Parameter estimates and significance levels for the final models are displayed in Tables 4 (SBP) and 5 (DBP). Girls had lower SBP (–2.70 mmHg, $p < .0001$) than boys. Those who were less mature had lower SBP than those who were more mature (–1.58 mmHg, $p < .0001$). Ethnic group was not related to SBP or DBP. Individual characteristics to control for confounding, as well as time-varying covariates, were statistically significant. Specifically, height covaried significantly with SBP; for each centimeter increase in height, SBP increased 0.23 mmHg. Mother's education was related significantly to DBP; participants with less mother's education had DBP 1.09 mmHg higher than those with more education ($p = .01$). Large effects of body position and activity on ambulatory SBP and DBP were observed ($p < .0001$). Location had significant but smaller effects.

As indicated in Table 4, the only significant interaction term in the mixed model for SBP was the Neutral × Gender × Ethnic × Maturation interaction. African American boys, particularly the more physically mature ones, and less mature African American girls, had higher SBP than other groups while feeling neutral.

The model for DBP (Table 5), with five significant interaction terms, was more complex. The three-way interaction of gender, ethnic group, and maturation was significant. Less mature, Hispanic American girls had higher DBP than other girls. Less mature adolescents had higher DBP while bored or rushed than did more mature adolescents. While feeling neutral, less mature African American girls and more mature Hispanic American girls had higher DBP than more mature European American girls. Feeling rushed was associated with higher DBP for more mature African American adolescents and less mature Hispanic and European American adolescents compared with the less mature African American and more mature European and Hispanic American adolescents. The addition of these interaction terms with "rushed" resulted in a reversal of the direction of the main effect of this variable to a negative, nonsignificant association.

To illustrate the findings for the associations between moods and ambulatory blood pressure, Figures 1 and 2 display the magnitude of the associations between each mood with SBP and DBP, with and without adjustments for all other variables and significant interaction terms. The moods irritable, sad, and stressed are not included in these figures because they were not significantly associated with either SBP or DBP, with or without adjustments. Rushed, excited, happy, or angry moods were associated with significantly higher SBP. Reports of being relaxed, being bored, accomplishing things, or feeling neutral were associated with significantly lower SBP. Except for reports of feeling neutral or angry, these associations with SBP remained significant after adjusting for other moods, gender, ethnic group, maturation, height, mother's education, activity, position, location, and interaction terms. Many of the same moods were related to DBP; however, the magnitude of the effects was smaller. Controlling for other variables, being excited or happy was associated with higher DBP, and being bored, interested, relaxed, or accomplishing things was associated with lower DBP.

TABLE 4
Mixed-Effects Model for 24-hr Ambulatory Systolic Blood Pressure in Adolescents, 11 to 16 Years Old in Houston, Texas

	Systolic Blood Pressure		
Parameter	*Parameter Estimate*	*SE*	*p*
Intercept	81.59	4.259	< .0001
Height (cm)	0.23	0.026	< .0001
Maturation (Tanner [30], Stages 1, 2, 3)[a]	–1.58	0.611	.01
Gender (Female)[b]	–2.70	0.503	< .0001
Ethnic (African American)[c]	–0.24	0.610	.70
Ethnic (Hispanic American)[c]	0.39	0.665	.56
Mother's education (≤ 12 years)[d]	1.09	0.579	.06
Position (reclining)[e]	–3.47	0.390	< .0001
Position (standing)[e]	5.37	0.243	< .0001
Location (other)[f]	1.71	0.385	< .0001
Location (school)[f]	0.79	0.359	.03
Activity (actigraph)	0.006	0.0009	< .0001
Angry	0.83	0.491	.09
Excited	1.53	0.322	< .0001
Accomplishing things	–0.94	0.260	.0003
Bored	–0.77	0.271	.004
Happy	0.74	0.278	.008
Interested	–0.39	0.285	.17
Irritable	–0.55	0.385	.15
Neutral	–0.15	0.745	.41
Rushed	1.08	0.335	.001
Sad	0.25	0.516	.63
Stressed	–0.28	0.343	.42
Relaxed	–0.86	0.272	.002

Note. Significant interaction term: Neutral × Ethnic × Gender × Maturity ($p = .008$).

[a]Reference category: Tanner (30) Stages 4 and 5 (more mature). [b]Reference category: male. [c]Reference category: European American. [d]Reference category: more than 12 years. [e]Reference category: sitting. [f]Reference category: home.

TABLE 5
Mixed-Effects Model for 24-hr Ambulatory Diastolic Blood Pressure in Adolescents, 11 to 16 Years Old in Houston, Texas

	Diastolic Blood Pressure		
Parameter	*Parameter Estimate*	*SE*	*p*
Intercept	66.67	3.243	< .0001
Height (cm)	0.03	0.019	.14
Maturation (Tanner [30], Stages 1, 2, 3)[a]	–1.82	0.978	.06
Gender (Female)[b]	1.23	1.031	.23
Ethnic (African American)[c]	–0.13	0.805	.88
Ethnic (Hispanic American)[c]	–1.54	0.877	.08
Mother's education (≤ 12 years)[d]	1.02	0.410	.01
Position (reclining)[e]	–5.23	0.347	< .0001
Position (standing)[e]	5.25	0.219	< .0001
Location (other)[f]	1.86	0.344	< .0001
Location (school)[f]	0.84	0.282	.003
Activity (actigraph)	0.006	0.0008	< .0001
Angry	0.69	0.437	.12
Excited	1.05	0.282	.0002
Accomplishing things	–0.57	0.229	.01
Bored	–1.35	0.294	< .0001
Happy	0.61	0.241	.01
Interested	–0.54	0.251	.03
Irritable	0.32	0.340	.34
Neutral	–1.04	0.719	.15
Rushed	–1.71	0.751	.02
Sad	0.57	0.445	.20
Stressed	–0.38	0.304	.21
Relaxed	–0.48	0.236	.04

Note. Significant interaction terms: Gender × Ethnic × Maturity ($p = .03$), Bored × Maturity ($p = .003$), Neutral × Gender × Maturity ($p = .007$), Rushed × Gender ($p = .03$), Rushed × Ethnic × Maturity ($p = .004$).

[a]Reference category: Tanner (30) Stages 4 and 5 (more mature). [b]Reference category: male. [c]Reference category: European American. [d]Reference category: more than 12 years. [e]Reference category: sitting. [f]Reference category: home.

DISCUSSION

Neutral and positive moods were much more prevalent than negative moods in this sample of adolescents. A similar pattern has been observed in a recent study of adolescents (33) and in several studies of adults (6,7,9,10,13). In terms of specific moods, previous studies have varied in reported frequencies. This may be due, at least in part, to differences among the samples and methods of measuring and describing mood states. Nevertheless, the relative rankings of frequencies of specific moods are remarkably similar among studies. For instance, reports of being angry are assessed in most studies, but occurrences of feeling angry are infrequent relative to other moods; sadness is a mood that has been included in several studies, but participants rarely report feeling sad.

The prevalence of some moods varied by ethnic group, gender, and maturation, with the greatest differences observed for more sexually mature compared with less sexually mature adolescents. More mature adolescents were more likely to report being sad, irritable, stressed, rushed, and accomplishing things than were less mature adolescents. The less mature adolescents were more likely to report feeling excited. Previous studies of affective states in adolescents indicate that puberty does not have a profound effect on the structure of mood during adolescence (21). Our findings indicate that puberty may bring a transition in the relative frequencies of specific moods reported. Longitudinal studies of adolescents over time would be required to more adequately assess developmental patterns. A few previous studies have tested gender and ethnic group differences in mood states. In a sample of normotensive adults 30 to 45 years old, there were no gender differences in the frequencies of reporting positive and negative moods (8). In a study of female nurses, Filipino women reported negative moods more frequently than Caucasian women (10). Further study of the modifying effects of gender, ethnic group, and stage of the life cycle

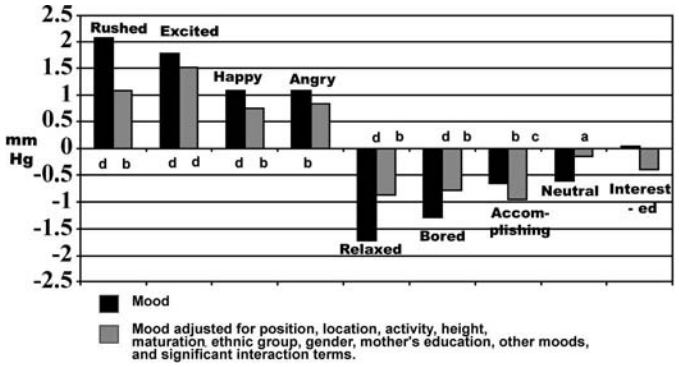

FIGURE 1 Associations between moods and ambulatory systolic blood pressure in adolescents, 11 to 16 years old, in Houston, Texas. a = $p < .05$; b = $p < .01$; c = $p < .001$; d = $p < .0001$.

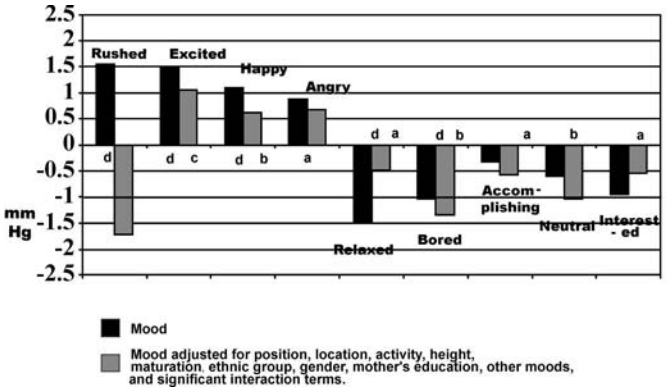

FIGURE 2 Associations between moods and ambulatory diastolic blood pressure in adolescents, 11 to 16 years old, in Houston, Texas. a = $p < .05$; b = $p < .01$; c = $p < .001$; d = $p < .0001$.

on reports of moods and their associations with cardiovascular responses is recommended.

A major objective of this study was to investigate the associations between mood states and ambulatory blood pressure in adolescents during the course of their daily activities on a school day. The magnitude of the associations between moods and ambulatory blood pressure in adolescents was small (about 0.5–3.5 mmHg). Although these are not large effects, the possibility exists that small changes such as these could lead to chronically higher levels of blood pressure if they were experienced over long periods of time. The observed effects of moods on blood pressure in this study are larger than in one previous study (8), about the same or slightly smaller than other studies (5,6,14), and much smaller than one other study (9). The controls for covariates were more stringent in this study than in some previous studies. Aside from methodological variations among studies, differences in effect sizes could be the result of different levels of stress experienced by these young, healthy participants and/or differences in autonomic control that buffers the physiological effects of moods. Further study may lead to expansion of the psychophysiological model of Sloan et al. (1) to explicitly account for changes in autonomic control resulting from maturational effects during childhood and adolescence.

Both positive and negative moods were associated with higher blood pressure, as in previous studies of adults (5–8). An examination of the specific moods associated with increases or decreases in blood pressure indicates that the patterns observed for these adolescents were very similar to previous studies of adults. Reports of being relaxed or bored were associated with lower blood pressure. These moods and others that reflect a subdued, low level of arousal, such as disengaged, sleepy, and tired, were associated with significantly lower levels of blood pressure in previous studies (5,6,8–10). In this study, reports of feeling rushed, excited, or happy were associated with increases in SBP and/or DBP. In previous studies, self-reports of being stressed, angry, anxious, excited, and happy have been associated with increases in blood pressure (5–7,9,10,13). These findings provide some support for the idea that it is the degree of engagement, rather than the negative aspect of emotions, that is associated with increases in blood pressure. An exception was "accomplishing things," a positive mood that implies a high rather than a low degree of engagement. It was associated with lower SBP and DBP. The emotional satisfaction that may accompany a sense of accomplishing things could explain the lower levels of blood pressure associated with it. Anger, which has been studied extensively as a trait measure in relation to blood pressure in youth as well as adults, was significantly related to SBP and DBP. This association was diminished to nonsignificant levels after covariates were included in the model. In contrast, anger was the mood associated with the largest increases in blood pressure in one study of adults, and this association remained significant after adjustments for position and location (6). Differences between adolescents and adults in the experience of anger, ability to buffer blood pressure responses to anger-provoking situations, and the possible role of autonomic control in explaining these differences should be investigated further. Systematic differences between adults and adolescents in the linkages between moment-to-moment changes in moods and variability in ambulatory blood pressure, if confirmed by further study, could provide a basis for expansion and refinement of the model presented by Sloan et al. (1).

Significant effects of moods on blood pressure were dampened but not eliminated by controlling for participant characteristics and time-dependent covariates of activity, position, and location. Position had the greatest effect on blood pressure. This underscores the importance of controlling for body position and activity at the time of each blood pressure measurement, as noted by others (6,10,29). However, not all authors agree on the need and reasons to control for other determinants of blood pressure that covary with moods (5,9). In this study, these variables were controlled because we were attempting to quantify effects of moods on blood pressure that could be observed over and above the physical effects of body position and activity.

Gender and maturation were significantly related to ambulatory blood pressure. Male adolescents had higher SBP than female adolescents. Similar gender differences in ambulatory blood pressure have also been noted in studies of adults

(8,12,14). In a model that controlled for all other variables, including height, the less sexually mature adolescents had lower blood pressure than the more mature adolescents. Sexual maturation has not been tested in previous studies of ambulatory blood pressure. Measurement of blood pressure during adolescence is complex because it is a period of rapid growth, and body size is closely related to blood pressure. On average, African American children mature at an earlier age, and Hispanic adolescents are shorter than Anglo or African American adolescents. Thus, some ethnic group differences in blood pressure are due to physical, rather than cultural, differences. Ethnic groups differences in blood pressure may also be secondary to socioeconomic factors or other environmental stressors, such as discrimination (34). Mother's education was significantly related to DBP, and control for this variable, as well as moods and physical factors such as height and maturation, reduced observable main effects of ethnic group on ambulatory blood pressure to statistically insignificant differences.

An examination of the modifying effects of gender, ethnic group, and maturation revealed significant effects. African American boys and less mature African American women had higher SBP while experiencing neutral moods than did other groups; higher DBP was observed for less mature African American and more mature African American girls while feeling neutral. These subgroups had higher SBP even in the absence of emotional arousal. Although it is expected that blood pressure rises in response to physically and emotionally challenging tasks, longer recovery times after challenge could result in sustained levels of cardiovascular arousal, leading to the enhanced risk for morbidity and mortality over long periods of time. The differences in blood pressure in the parameter estimates for these interaction terms ranged from 2.0 to 3.0 mmHg for SBP and from 2.0 to 3.6 mmHg for DBP. Although these are not large effects, they are at least as large as any of the main effects in the mixed models. If large portions of the population experienced these slightly higher levels, the impact on morbidity and mortality could be substantial (35).

This was a volunteer, nonprobability sample that does not necessarily represent the population of the school district from which it was drawn. The students not only had to obtain parental consent but also had to be willing to participate in all the research protocols, including ambulatory blood pressure monitoring. Furthermore, the ambulatory monitoring of blood pressure may have affected the moods reported by the participants. In our experience, some participants find the monitoring irritating, and those most intolerant may have been among those who did not successfully complete the protocol and those who did not volunteer for the study. In addition, because the ambulatory measurements were taken at fixed, predictable intervals, the participants may have modified their locations, activities, or interactions in anticipation of cuff inflation. Monitoring was limited to 1 day; more days may be required to capture an adequate sample of moods that are reported relatively infrequently.

Most of the research on the links between psychological variables and cardiovascular outcomes has been based on trait measurements (36). The findings of this study, which are based on intermittent state measurements, do not rule out the possibility that, over the long term, cardiovascular risk accrues to people who frequently experience negative emotions and/or those who have diminished ability to buffer blood pressure responses to challenge. These hypotheses cannot be tested with intermittent ambulatory blood pressure measurements. More detailed studies are of adolescents are recommended.

Major strengths of this study include the ethnic diversity and size of this sample of adolescents. Limited data are available on the links between moods and ambulatory blood pressure in healthy individuals, and few studies of this type with samples of youths other than college students are available. Another strength of this investigation was the detailed measurement and control of important confounding variables in making inferences about ambulatory blood pressure. In addition to demographic variables and body size, we also objectively measured and controlled for differences in sexual maturation, a variable that has not been considered in previous studies (26,27). Some investigators might object to measurement of sexual maturation as it entails a clinical examination and may cause embarrassment. Indeed, some potential participants might have declined in order to avoid the ordeal of a physical examination, further limiting the representativeness of the sample. Other investigators may want to consider self-report methods that have some evidence of reliability and validity and could be used for nonclinical samples (37–39). Finally, this study was enhanced by use of a mixed model in statistical analysis, making it possible to compare the findings with those of recent studies that have used a similar approach.

Links between adolescent blood pressures levels and their moods may provide a basis for designing psychosocial interventions to complement standard cardiovascular disease prevention strategies. Understanding the pathways that lead to greater blood pressure variability in response to challenge could provide a basis for identifying high-risk groups early in life. Lowering blood pressure in the adolescent population, if maintained into adulthood, could have a major impact on cardiovascular disease morbidity and mortality.

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