Hypertension
Clinical Studies

Effects of Race and Marginally Elevated Blood Pressure on Responses to Stress

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SUMMARY A total of 228 men, aged 18 to 22 years (109 black and 119 white), underwent monitoring of heart rate (HR) and systolic (SBP) and diastolic blood pressure (DBP) responses during several stressor conditions and a 30-minute posttask rest period. Stressors included the cold pressor test and three reaction-time tasks: noncompetitive, competitive, and competitive plus money incentive. Substantial within-subject variations in blood pressure and heart rate were induced, varying from 119/70 to 148/94 mm Hg and from 63 to 91 beats/min on the average. Men (25 black and 39 white) with marginal SBP elevations during initial casual determinations had higher SBP under all conditions compared with men whose casual SBP levels were normal, and they also showed greater elevations over baseline levels in heart rate, SBP, and DBP during the stressors and the initial casual determination. Black and white subjects did not differ in their blood pressures at baseline or during the initial casual determinations, although blacks had slightly lower heart rates. Blacks did show greater SBP elevations over baseline levels than whites during the stressors, primarily because the blacks with marginally elevated SBP showed substantially greater stress-induced increases than whites with marginally elevated SBP. This enhanced pressor response to stress in blacks with marginal blood pressure elevations may be due to higher vascular resistance during enhanced sympathetic activity and could contribute to the higher incidence of hypertension among blacks.

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KEY WORDS • race • borderline hypertension • psychological stress • sympathetic nervous system • black population • cardiovascular reactivity

In the United States, the prevalence of essential hypertension is almost twice as high among blacks as among whites.1 Although genetic factors may contribute to racial group differences,2,3 exposure to environmental stressors may also play a major role. High life stress has been assessed in epidemiological studies through its association with low socioeconomic status, social instability, crowded living quarters, and high neighborhood crime rate. In these investigations, indicators of high life stress were associated with higher average blood pressure (BP) or hypertension-related mortality in both blacks and whites; however, a greater proportion of the black samples were typically found to belong to the groups exposed to these stressors.4-7

In addition, it has been hypothesized that even routine life stresses, like those of daily life at work and at home, may elicit greater physiological responses from blacks. Physical stressors, such as postural change, cycle and treadmill exercise, and the application of ice to the arm or forehead, have been shown to elicit greater BP increases among black than among white children and college students.8-11 In some studies, this enhanced pressor response in blacks was observed only among those with marginally elevated BP or a family history of hypertension.9,10 These findings are especially intriguing since young whites with borderline hypertension or hypertensive parents (or both) have been shown to exhibit exaggerated BP and heart rate (HR) responses to physical and, especially, psychological stressors compared with persons without these risk factors for hypertension.12-15 If BP increases during psychological stressors, which are more similar to natural life events, could also be shown to be greater among black than among white subjects at higher risk for hypertension, it would substantially strengthen the
hypothesis that exposure to daily life stressors may contribute to the increased incidence of hypertension among the black population in the United States.

There have been few published studies comparing cardiovascular responses to psychological stressors in black and white subjects. The most extensive effort to date was an investigation of BP and HR responses to video game tasks in 213 black and white children by Murphy et al. The black children showed greater increases in systolic (SBP) and diastolic blood pressure (DBP) during the tasks than the white children. In contrast, in a group of adults, which included a sub-group with borderline hypertension, Fredrikson found that regardless of BP status, blacks showed lesser SBP and HR responses but greater increases in hand and calf vascular resistance than whites when exposed to an aversive reaction-time task. However, these comparisons were based on only two black men and three black women with borderline hypertension and only 15 blacks in all BP status groups, a relatively small sample. Thus, it is uncertain whether the increased BP reactivity to psychological stressors observed among black children persists in adulthood, and also whether this greater reactivity can be demonstrated among black persons at increased risk for hypertension, such as those with borderline hypertension.

The present study was designed to compare HR, SBP, and DBP responses to physical and psychological stressors in a large sample (n = 228) of black and white adult subjects. To ensure that the black and white samples were well matched for sex and age, we restricted our subjects to men aged 18 to 22 years. Also, to permit us to focus particularly on black and white subjects at higher risk for hypertension, subjects with marginally elevated BP were grouped separately from those with normal BP.

**Subjects and Methods**

A total of 230 male undergraduate college students, including 110 black and 120 white men, underwent physiological monitoring during a single 2½ hour session involving exposure to a series of laboratory stressors and a prolonged poststressor relaxation period. All participants read a detailed description of the procedures and provided written informed consent before beginning the protocol. Subjects received their choice of either financial reimbursement alone for their time or a lesser financial reward plus experiment credit time applied toward a research experience requirement for their introductory psychology course. In addition, all subjects were informed that they would receive an additional money bonus if they won the task involving a money incentive.

Subjects were tested in pairs since two of the stressors involved direct interpersonal competition; 74 black and 84 white subjects were tested in same-race pairs, while the remaining 72 subjects were tested in different-race pairs. Analyses comparing responses as a function of race and pairing type were performed to determine whether same-race and different-race pairs differed in their cardiovascular responses to these tasks (see Results).

None of the participants had a medical history of sustained hypertension or any serious cardiovascular or renal disorders. One subject was later omitted due to evidence of sustained diastolic hypertension (≥90 mm Hg), and another was omitted because his age was above the 18- to 22-year range selected for this sample, leaving a final sample of 109 black and 119 white subjects. Loss of BP or HR data due to movement artifact or equipment problems reduced the sample size slightly more under certain task conditions, with the greatest loss (n = 12) occurring for DBP during the cold pressor test.

For the purposes of data analysis, subjects were grouped according to race and according to the presence or absence of marginally elevated BP. Racial group was ascertained by response to a written question, while initial casual stethoscopically determined SBPs of 135 to 154 mm Hg were used to identify men with marginally elevated BP. This definition was selected to be consistent with our previous study, in which a group of predominantly white male college students with marginally elevated initial SBPs were found to show greater cardiovascular responses to a similar reaction-time task than those with lower initial SBPs. The possibility of also including additional subjects with stethoscopic SBPs below 135 mm Hg but with stethoscopic DBPs of 85 mm Hg or higher was considered but rejected because this rarely occurred (only 6% of the sample) and because of the desire to keep the groups with marginally elevated pressure as homogeneous as possible. Among the 119 white subjects, 39 (33%) had marginal SBP elevations, while 80 (67%) had normal SBP (<135 mm Hg). Among the 109 black subjects, 25 (23%) had marginally elevated SBP and 84 (77%) had normal SBP (Table 1). Group comparisons confirmed that black and white subjects within the two SBP status groups did not differ in their initial stethoscopic SBPs, although whites had higher HRs than blacks during this BP determination (p < 0.04). Subjects with elevated SBP during the stethoscopic determination had higher DBP and HR levels at that time as well (both, p < 0.006). Further comparisons confirmed that black and white groups with and without marginal SBP elevations did not differ in age, height, or ponderal index, which was calculated as height/(weight)² (F₁, 223 < 1.95, p > 0.16 for all comparisons).

**Equipment and Physiological Recording**

All physiological data were recorded on a Beckman Type R Dynograph (Sensormedics, Anaheim, CA, USA). HR was obtained from the electrocardiogram recorded from electrodes placed on either side of the rib cage. Arterial BP measurements were made using the auscultatory method. A standard inflatable cuff, placed around the nondominant arm, was rapidly inflated and then slowly deflated using an automated laboratory-constructed system. Pulses from a piezoelectric microphone (Model DIV 705-0018; Narco Bio-Systems, Houston, TX, USA), positioned over the brachial artery and under the edge of the cuff, were recorded on the chart using a separate channel...
adjacent to the one used to record cuff pressure. SBP and DBP were identified as the onset (Phase I) and disappearance (Phase V) of Korotkoff sounds, respectively.

**Experimental Procedures**

Following consent procedures, the two paired subjects were led to the experimental chamber and seated side by side in two comfortable armchairs. To minimize effects of the race of the experimenter on cardiovascular response, a pair of female research assistants, one black and one white, worked together to instrument the subjects with the electrocardiographic electrodes and the BP cuff, to give task instructions, and to evaluate task performance. Operation of equipment and recording of data were performed in a separate, adjacent room.

Following instrumentation (approximately 20–30 minutes after their arrival and 10 minutes after being seated in the chamber), initial casual BP determinations were made by the research assistant by placing a stethoscope below the cuff to listen for Korotkoff sounds as the cuff deflated. The cuff pressure and Korotkoff sounds detected by the microphone beneath the lower edge of the cuff were recorded simultaneously on the chart record. These initial readings (like all subsequent readings) were scored from the chart record, not from the stethoscopically detected Korotkoff sounds, so as to ensure comparability with later readings when no listener and stethoscope were used. A second and, occasionally, a third reading were made with the assistant applying the stethoscope if needed to obtain a clear chart-record determination of whether initial casual SBP levels exceeded or were below the criterion of 135 mm Hg.

Following the casual BP determinations, the assistant instructed the subjects to rest quietly for 10 minutes and then left the chamber. Throughout this period, HR was recorded continuously and BP readings were obtained once per minute. The data obtained from the last 5 minutes of the period were averaged together to represent pretask resting levels.

The next event was the cold pressor test, which involved immersion of the foot for 90 seconds in a pan filled with crushed ice and a small quantity of water, to an average temperature of 4°C. By fully deflating and then immediately reinflating the BP cuffs as soon as the first deflation fell to 50 mm Hg, two BP readings were obtained during this brief stressor. A 5-minute post-cold pressor rest period followed.

The next three stressors were all reaction-time tasks, each 6 minutes long, involving 20 respond stimuli (photographic slides reading either GO or NO projected on a screen) presented at varying intertrial intervals (mean, 18 seconds; range, 8–38 seconds). The first of these was the noncompetitive task. In this task, subjects were told to respond by pressing a switch with their right index finger as fast as possible whenever the word GO appeared, but not to respond when the word NO appeared. Subjects were specifically instructed that they were not competing with anyone else, but that they were instead to try to achieve times that were progressively faster than their own previous times as they got more practice with the task. A screen was drawn between the subjects to prevent them from observing the other subject or his reaction time, although they could always observe their own reaction times recorded by two digital stopclocks (Model 54519-A; Lafayette Instruments, Lafayette, IN, USA). The research assistant remained in the chamber during this and the two later reaction-time tasks, seated behind the subjects writing their reaction times on a clipboard score sheet, in order to monitor their performance in an overt way.

The next two stressors were the competitive task with no incentive and the competitive task with money incentive, which were presented in counterbalanced order across subjects. In both tasks, to emphasize competitive stimuli, the screen between the subjects was removed and the stopclocks repositioned so that the subject could see both his own and his competitor's reaction times. In the first competitive task, whether for an incentive or not, one subject was initially instructed to respond if the word GO appeared, while his competitor was to respond if the word NO appeared. In the second task, which used the same words in different sequence, one subject was initially told to respond if the word that appeared was the same as the preceding one, while the other subject was to respond if they were different. To increase task difficulty, after every two to five trials, the research assistant would say “Switch,” and then each subject had to respond instead to the alternate strategy. Subjects were instructed that the object was to try to achieve a lower total time for the entire task than that of their competitors. Also, whenever the subject responded to the incorrect word

### TABLE 1. Cardiovascular Responses During Initial Casual Stethoscopic BP Determinations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Black (n = 25)</th>
<th>White (n = 39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP (mm Hg)</td>
<td>140.0 ± 1.3*</td>
<td>141.4 ± 0.7*</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>79.2 ± 1.9*</td>
<td>81.4 ± 1.2*</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>73.1 ± 2.2*</td>
<td>76.5 ± 2.3*†</td>
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Values are means ± SE.

* p < 0.006, compared with values for subjects with normal SBP, even after adjustment for differences evident under the more basal lowest rest condition.

† p < 0.04, compared with respective value in black subjects.
or failed to respond to the correct word, a 2-second penalty was added to his total time, making the outcome of the competition uncertain until the last of the 20 trials had been completed. For the no-incentive task, subjects were instructed that they would be informed at the end which subject had achieved the lower total time and was the winner. For the money-incentive task, subjects were instructed that the task was winner-take-all and that the one with the lower total time would win a $10 bonus. BP and HR were monitored during each minute of these tasks, with 5-minute periods for recovery between tasks.

After the last stressor, a 30-minute posttask rest occurred, with BP and HR recorded in Minutes 1 to 3, 7 to 9, 14 to 16, 21 to 23, and 28 to 30. To facilitate relaxation, the screen was again drawn between the subjects, the lights were dimmed, and each subject was asked to wear earphones through which a tape recording of gentle wave sounds was presented. Data gathered during the rest period were used to evaluate rates of recovery from the stressors and to yield baseline levels approaching basal levels. On average, the lowest levels were obtained during Minutes 21 to 30 of posttask relaxation, but subjects varied in whether their responses rose or fell during the last 3 minutes of the 30-minute rest, possibly because of occasional early anticipation of the end of the study. To obtain values as close to basal levels as possible, the lowest rest baselines for SBP, DBP, or HR were calculated by averaging the two lowest consecutive resting readings, regardless of when they occurred.

After this 30-minute relaxation period, the monitoring devices were removed and the subjects were escorted to different rooms and asked to complete a series of questionnaires, including a comparison of the reaction-time tasks in terms of perceived stressfulness and how hard they were trying, information on parental socioeconomic status, family health history, weekly aerobic exercise, and personality traits. With the exception of the task comparisons, these results will be dealt with in subsequent separate communications.

Design and Data Analyses

All data analyses performed in this study were based on analysis of variance and covariance using a 2 X 2 race by SBP status design. Since cardiovascular data were obtained under many different conditions, as a protection against obtaining chance findings, preliminary analyses of variance for repeated measures were performed with the eight resting conditions included in one analysis (initial stethoscopic BP determination, lowest rest, pretask rest, and posttask rest Minutes 1–3, 7–9, 14–16, 21–23, and 28–30) and the four stressor conditions in a second analysis (cold pressor, noncompetitive reaction time, competitive task with no incentive, and competitive task with money incentive). Group differences during individual conditions were evaluated by subsequent univariate analysis of variance only if a significant interaction between one of the grouping factors and resting or stressor conditions was obtained. It was also recognized that any group differences observed during the stressors might involve two contributions: differences already present at baseline plus any additional effect of differential reactivity to the specific stressor. According to Matthews' in her recent summary of the conclusions of a National Institutes of Health-sponsored conference on stress, reactivity, and cardiovascular disease, a group may only be said to show greater reactivity in response to a discrete environmental stimulus, and then only if such differences in response remain after statistical correction for differences present at baseline or control levels. To evaluate differences in reactivity to the four stressors in this study after correcting for differences present at baseline, the technique of analysis of covariance was used, with the lowest rest baseline measure employed as the covariate. As Lee has demonstrated, analysis of covariance is more appropriate than analysis based on simple change scores (stress minus baseline levels) under circumstances where "regression to the mean" or similar phenomena associated with repeated-measurement data may occur because this method corrects for such confounding. The lowest rest measure was selected as the baseline rather than stethoscopic BP levels in part because it was statistically more appropriate to use as a dependent variable since stethoscopic BP levels had been used to determine subject groups, and it is desirable to separate independent from dependent variables. An even more important reason for this choice was that the lowest rest measures were the closest approximation available to the basal state, where uncontrolled stressful effects associated with anticipation of stressors or later carryover from stressors or simply being monitored by a health professional with a stethoscope were at a minimum.

Individual task performance during the three reaction-time tasks was assessed using total time for each task, a measure reflecting accuracy as well as speed since it includes time penalties for errors. A related measure of group task performance was the percentage of winners during the two competitive tasks in the black versus white groups and the elevated versus normal casual SBP groups. When analyses of variance and covariance yielded a significant $F$ ratio, subsequent comparisons among group means were performed using the Tukey honestly significant difference (HSD) test.

Results

Effects of Resting and Stressor Conditions on Cardiovascular Responses

Reliable differences in the levels of HR, SBP, and DBP were obtained over the eight resting conditions ($F_{7,112} = 80.9, p < 0.0001$ for all comparisons). SBP, DBP, and HR levels during the initial stethoscopic BP determination were higher than during the subsequent pretask rest, when no stethoscope or listener was used ($p < 0.01$ for all comparisons). During the 30-minute posttask rest, SBP levels fell significantly from the
onset to each later period \(p<0.01\) for all comparisons; Figure 1), while DBP and HR levels declined significantly from Minutes 1 to 3 to Minutes 14 to 16 \(p<0.01\) for all comparisons; Figures 2 and 3) but remained generally unchanged after that time. The lowest rest baseline levels for SBP, DBP, and HR were significantly lower than levels in the pretask rest or any of the specific posttask rest periods \(p<0.01\) for all comparisons).

The four stressor conditions each evoked substantial increases in SBP, DBP, and HR over baseline levels. The range in values for a single subject averaged from 119/70 mm Hg at lowest rest to a peak during the stressors of 148/94 mm Hg and from 63 to 91 beats/ min. However, the four stressors did differ reliably in the magnitude of the responses they induced \((F_{3,642}>58.0, p<0.0001\) for all comparisons). As expected, the competitive task with money incentive evoked greater SBP, DBP, and HR responses than the competitive task with no incentive \((p<0.05\) for all comparisons; see Figures 1–3). Also, SBP, DBP, and HR responses to both competitive tasks were greater than those during the noncompetitive task \(p<0.01\) for all comparisons). During the cold pressor test, DBP responses were substantially higher than responses during any of the reaction-time tasks \(p<0.001\) for all comparisons; see Figure 2), while SBP and HR responses exceeded those of all tasks but the competitive task with money incentive, which evoked similar SBP and higher HR levels \(p<0.05\) for all comparisons; see Figures 1 and 3).

Cardiovascular Effects of Casual SBP Status

Men with marginally elevated SBP at the initial stethoscopic readings were found to have higher SBP and DBP levels than men with normal SBP under all conditions (see Figures 1 and 2). This finding was
indicated by significant main effects of SBP status for both SBP and DBP measures under resting conditions ($F_{1,214} = 125.1$ and $16.3$, respectively, $p<0.0001$) as well as under stressor conditions ($F_{1,214} = 104.8$ and $15.5$, respectively, $p<0.0001$). Subjects with marginally elevated SBP also had generally higher HR than those with normal SBP under the stressor conditions ($F_{1,224} = 61.0$, $p<0.015$; see Figure 3), but then showed only a trend in this direction under most resting conditions ($F_{1,218} = 3.36$, $p<0.07$).

The differences between the men with and without marginal SBP elevations were greater during the stethoscopic determination than during other resting conditions. This resulted in significant interactions between SBP status and resting conditions for SBP and HR ($F_{1,192} = 10.5$ and $2.16$, respectively, $p<0.035$). During the lowest rest baseline, the pretask rest, and throughout most of the 30-minute posttask rest, men with marginally elevated SBP consistently averaged 12 to 13 mm Hg higher in SBP, 3 mm Hg higher in DBP, and 2 beats/min higher in HR than those with normal SBP. However, during the stethoscopic determination, these group differences increased to 18.2 mm Hg for SBP, 5.3 mm Hg for DBP, and 4.6 beats/min for HR. Analysis of covariance confirmed that the subjects with marginal SBP elevations showed greater SBP, DBP, and HR responses to the stethoscopic determination even after adjustment for differences evident at the lowest rest baseline ($F_{1,211} = 98.8$, 13.8, and 7.71, respectively, $p<0.006$ for all comparisons).

Responses during the early and later time intervals of the 30-minute posttask rest were analyzed to determine whether SBP status was related to differences in rate of recovery to baseline. After covariance adjustment for lowest rest levels, subjects with marginal SBP elevations showed a trend for SBP and DBP to remain roughly 2 mm Hg more elevated than in subjects with normal BP during Minutes 1 to 3 of the posttask rest ($F_{1,219} = 3.29$ and $3.63$, $p<0.007$). This trend toward modest group differences after adjustment for baseline persisted for DBP but not SBP into posttask Minutes 7 to 9 and 14 to 16 ($F_{1,218} = 2.71$ and $4.5$, $p = 0.10$ and 0.035) but was entirely absent during the second half of the posttask rest. Although these effects were not pronounced, they do suggest a tendency for BP in subjects with, versus subjects without, marginally elevated SBP to return to baseline levels more slowly after stressor conditions.

During the three reaction-time tasks, differences in cardiovascular responses between men with and without marginally elevated SBP were significantly greater than differences obtained at baseline. In contrast, during the cold pressor test, differences between these groups in SBP, DBP, and HR were no greater than at baseline. Significant interactions between SBP status and stressor conditions were obtained for SBP, DBP, and HR, indicating that group differences were greater under some conditions than others ($F_{3,64} = 3.45$, 2.64, and 15.5, respectively, $p<0.05$ for all comparisons). Subsequent analyses comparing the data of the high and low casual SBP groups for each individual task revealed that, after covariance adjustment for group differences present at baseline, the subjects with elevated casual SBP no longer showed significantly higher SBP, DBP, and HR responses during the cold pressor test ($F<1$, $p>0.65$ for all comparisons). In contrast, after adjusting responses during each of the three reaction-time tasks for baseline levels, men with elevated casual SBP still showed greater SBP ($F_{1,220} = 10.9$, $p<0.001$; Figure 4; see also Figure 1), DBP ($F_{1,220} = 5.77$, $p<0.02$; see Figure 2), and HR elevations ($F_{1,221} = 4.88$, $p<0.03$; see Figure 3) than those with normal casual SBP.

**Cardiovascular Effects of Racial Group**

Black and white subjects did not differ in their SBP or DBP responses during any of the resting conditions, including the lowest rest baseline, the pretask rest, and all time intervals of the 30-minute posttask rest ($F_{1,216} = 2.6$ and 0.2, respectively, $p>0.10$ for all comparisons). However, HR levels during resting conditions did differ between racial groups, with black subjects showing lower HR than white subjects ($F_{1,218} = 7.77$, $p<0.006$; see Figure 3).

During the stressor conditions, black subjects showed greater SBP responses than white subjects ($F_{1,221} = 9.95$, $p<0.002$; see Figure 1). Racial group differences were fairly similar across the cold pressor test and all three reaction-time tasks. However, the difference between black and white subjects was not equal for the higher and lower casual SBP subgroups, it was much greater among those with marginal SBP elevations (race × SBP status interaction, $F_{1,221} = 4.89$, $p<0.03$). Subsequent comparisons among means confirmed that blacks with elevated casual SBP showed consistently greater SBP responses to the various stressors than whites with elevated casual SBP, after covariance adjustment for baseline levels ($p<0.05$; see Figure 4). Blacks with normal casual SBP tended to show slightly greater SBP responses during the stressors than their white counterparts, but these differences were not statistically significant when considered independently. No racial group differences in DBP or HR responses to the stressors were obtained after adjusting for baseline levels ($F_{1,221} = 2.67$, $p>0.10$ for all comparisons; see Figures 2 and 3), although the HR differences present at baseline were maintained.

Analyses were also performed to determine whether the effects of racial group on cardiovascular responses might have been influenced by the racial makeup of the pairing for competition. Same-race and different-race pairs did not differ in their SBP or DBP responses to either of the competitive tasks ($F_{1,218} < 1.1$, $p>0.30$ for all comparisons). However, for HR there was a trend only during the competition task with no incentive toward an interaction between pairing and race ($F_{1,218} = 3.37$, $p = 0.067$), resulting from whites tending to show higher HR in same-race versus different-race pairs (86.4 vs 83.1 beats/min), while blacks tended to have lower HR in same-race versus different-race pairs (83.5 vs 86.6 beats/min). Altogether, these find-
ings indicate that the race of the competitor was not a major factor influencing the magnitude of responses to the competitive tasks in this sample.

**Reaction-Time Task Performance and Postexperimental Task Evaluations by Subjects**

Black and white subjects did not differ in their reaction-time performance on any of the three tasks ($F_{1,224} < 1, p > 0.55$ for all comparisons). Likewise, subjects with elevated versus normal casual SBP did not differ in reaction-time performance ($F_{1,224} < 2.28, p > 0.13$ for all comparisons). Also, there were no significant racial group or SBP status group differences in the percentages of subjects who were winners during the two competitive tasks (black, 51%; white, 48%; marginally elevated SBP, 51%; normal SBP, 48%). Furthermore, efforts to use reaction time and winner-loser status as covariates in the analysis of SBP responses to the tasks revealed that neither variable was significantly related to SBP responses (covariate $F_{1,218} < 1.5, p > 0.20$ for all comparisons). Thus, the observed differences in cardiovascular responses to these stressors are unlikely to be related to any systematic group difference in the way subjects interacted with their competitors or performed on the tasks.

In response to a postexperimental questionnaire asking subjects to compare the three reaction-time tasks in terms of stressfulness and how hard they had been trying, all groups gave similar answers. Over all subjects, the competitive task with money incentive was reported as the most stressful by 93% and as eliciting the most effort by 92% of the sample, with the remaining 7% and 8% choosing the competitive task with no incentive. All of the subjects rated the noncompetitive task as the lowest of the three on both these dimensions.

**Discussion**

The results of the present investigation confirm the findings of numerous earlier studies showing that subjects with marginally elevated BPs demonstrate greater BP and HR responses to challenging psychological tasks than normotensive subjects. However, in the present sample, subjects with marginal pressure elevations were not more reactive than those with normal BP to the physical stressor, the cold pressor test. This difference may be due to the fact that the reaction time tasks predominantly tend to elicit increased $\beta$-adrenergic receptor activity, while the cold pressor test elicits less $\beta$-adrenergic receptor activity but substantially greater $\alpha$-adrenergic receptor activity. Hemodynamic studies in young adults with borderline hypertension indicate that these persons frequently demonstrate increased cardiac output that is largely diminished by administration of $\beta$-antagonists. The differences in reactivity across tasks may also be related to specific behavioral factors, such as the opportunity to actively influence the event’s outcome (active coping) rather than to passively endure the event without being able to influence its outcome (passive coping).

In response to a postexperimental questionnaire asking subjects to compare the three reaction-time tasks in terms of stressfulness and how hard they had been trying, all groups gave similar answers. Over all subjects, the competitive task with money incentive was reported as the most stressful by 93% and as eliciting the most effort by 92% of the sample. The young black men in this sample, particularly those with marginally elevated BP, showed greater SBP responses during the stressors than their white counterparts. These results indicate that the greater

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**Figure 4.** Mean SBP levels of the four subject groups during the four stressor conditions after covariance adjustment for differences present at baseline. Values for subjects with marginally elevated SBP (---) exceeded those for subjects with normal SBP (-----) during the three psychological stressors (all $p < 0.001$) but not during the cold pressor test. Similar group differences as a function of SBP status after adjustment for baseline were also obtained for DBP and HR only during the psychological stressors (all $p < 0.03$; data not depicted). Values for black subjects (▲) exceeded those for white subjects (○) during all stressors ($p < 0.002$), a difference that was greater between the subgroups with elevated SBP ($p < 0.03$). RT = reaction time.
pressor responses to stress observed by Murphy et al. 16 in black children extend to the early years of adulthood as well. Furthermore, the present study strengthens the hypothesis that high stress reactivity among blacks may be related to their increased risk of hypertension by demonstrating that the racial group differences observed in reactivity were due primarily to the black subjects with marginally elevated BP, an established risk factor for hypertension.

The present findings on BP reactivity are not consistent with those of Fredrikson,17 who observed decreased SBP response to stress in his small sample of blacks, who were older (average age, 43.5 years) and mostly female rather than male subjects. However, Fredrikson did report that the black subjects in his study showed greater increases in vascular resistance than the white subjects. Similarly, Anderson et al.11 found that black college students show greater increases in forearm vascular resistance as well as BP compared with whites in response to an ice pack placed on the forehead, a stimulus that elicits skeletal muscle vasoconstriction much like the diving reflex. The increased SBP responses to the stressors shown by the blacks with marginal BP elevations in the current study probably are due primarily to greater total peripheral resistance rather than higher cardiac output responses. This interpretation is based in part on the finding that the black subjects did not show greater HR responses than the white subjects. In addition, we have since completed a follow-up study in 40 of these same subjects (20 blacks and 20 whites) using impedance cardiography to assess changes in cardiac output and total peripheral resistance during two repetitions of the competitive task with money incentive, one before and one after β-blockade with propranolol (unpublished observations, 1987). The results from this follow-up investigation replicated the original finding of greater SBP responses to this task among black versus white subjects with marginally elevated BP. This greater pressor response in blacks with marginal pressure elevations was associated with higher peripheral resistance than in whites during the task, an effect that was further enhanced following β-blockade, suggesting possible α-adrenergic mediation.

In their study of cardiovascular reactivity to stress among children, Murphy et al. 16 found that cardiovascular responses to the video games used as stressors were enhanced if the child and experimenter were of the same race. These researchers suggested that if same-race interactions can be shown to elicit consistently greater pressor responses, these interactions may have greater etiological importance. In the present study, the influence of experimenter race was minimized by using a team including both a black and a white experimenter. However, the race of the competitor was varied systematically, and this factor was found to have no consistent effect on the magnitude of cardiovascular responses to the tasks. This finding may indicate that same-race versus different-race interactions do not always have differential effects on cardiovascular responses, but may instead be modulated by other factors, such as whether the interaction is with a superior or a peer.

High cardiovascular reactivity to stress has been hypothesized for decades to be a factor of etiological importance in hypertension.25 Longitudinal studies attempting to verify that high reactivity to the cold pressor test predicts risk of later hypertension have yielded inconsistent results.30-34 However, this inconsistency may be due to the unusual nature of this stressor, which has no common parallels in real life. In contrast, psychological stressors similar to the noncompetitive and competitive tasks in this study are normal events in daily life for most persons in Western society. A recent longitudinal study by Falkner et al.35 involving adolescents with BP in the highest percentiles for their age indicated that high cardiovascular response to a more naturalistic psychological stressor (mental arithmetic) did predict maintenance of BP elevations over the next several years. In a similar 5-year follow-up study involving borderline hypertensive adults, Borghi et al.36 found that hypertension developed in a large majority of the high DBP responders, but not in the low DBP responders, during and after mental arithmetic. These observations suggest that high cardiovascular reactivity to psychological stressors may be a better predictor of later sustained hypertension than reactivity to the cold pressor test. Research evaluating the association between high cardiovascular reactivity to laboratory psychological stressors and real-life events using ambulatory monitoring has begun, and this line of evidence will also help clarify this issue.37,38 However, additional longitudinal studies on the long-term significance of high reactivity to psychological stress in blacks and whites are still needed and appear well warranted. These investigations may be more productive if the cardiovascular reactivity factor is evaluated in interaction with indices of stressful life demands, such as occupation, socioeconomic status, and family situation.

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