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High resting blood pressure is associated with decreased pain sensitivity. This study was designed to explore this relation in young, normotensive men and women. Twenty-nine women (mean age 19.1, range 18–29) and 26 men (mean age 19.3, range 18–25) rested for 10 min while systolic, diastolic, and mean arterial blood pressures were measured. They were then asked to complete a 2-min cold pressor task. Participants were asked to fill out the short form of the McGill Pain Questionnaire immediately after the pain task. Hierarchical regression analyses were performed to predict pain sensitivity from resting blood pressure, gender, and the interaction of resting blood pressure and gender. Resting systolic blood pressure was a significant predictor of pain sensitivity. Gender and the interaction between resting blood pressure and gender were not related to pain sensitivity. This suggests that the relation between resting blood pressure and pain sensitivity may be similar in men and women, at least in response to a cold pressor challenge.

Key words: pain, blood pressure, gender

Hypertensive humans and other animals have reduced pain sensitivity compared with normotensives (France & Ditto, 1996; Ghione, 1996). For example, hypertensive rats show reduced responses on the paw lick and other tests of pain sensitivity (Randich & Maixner, 1981). Moreover, hypertensive humans show similar decreases in pain sensitivity on tests such as tooth-pulp stimulation (Zamir & Shuber, 1980). It was unclear whether these antinociceptive effects of hypertension reflected a pathophysiological condition or a normal pain regulatory mechanism. However, McCubbin and colleagues (Bruehl, Carlson, & McCubbin, 1992;

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McCubbin & Bruehl, 1994) showed that the relation between resting blood pressure and pain sensitivity extends throughout the normotensive range. In addition, other researchers (Al'Absi, Buchanan, & Lovallo, 1996; Ditto, Seguin, Boulerice, Pihl, & Tremblay, 1998; France, Ditto, & Adler, 1991; Stewart & France, 1996) have shown that pain sensitivity is reduced in normotensive populations at risk for hypertension. The precise nature and demographics of this relation between blood pressure and pain remain to be elucidated.

There has been considerable work on the neurocirculatory mechanisms of pain sensitivity, and one or more of these mechanisms could mediate gender differences. Nevertheless, the role of baroreflexes in antinociception remains unclear (cf. Elbert et al., 1988; France et al., 1991; McCubbin & Bruehl, 1994). Endogenous opioid mechanisms may play a central role in the relation between blood pressure and pain sensitivity. McCubbin, Kizer, and Lipton (1984) found that the opioid antagonist naloxone prevented stress-induced analgesia and avoidance deficits in rats exposed to inescapable stress. Other researchers have found that opioid antagonists abolished differences in pain sensitivity between hypertensive and normotensive animals (Maixner, Touw, Brody, Gebhart, & Long, 1982; Zamir, Simantov, & Segal, 1980). Sheps et al. (1992) found higher plasma β-endorphin and lower pain sensitivity in hypertensive humans compared with normotensive controls. However, McCubbin and Bruehl (1994) suggested that the relation between resting blood pressure and pain sensitivity may involve both opioid and nonopioid mechanisms. A number of other potential mechanisms could produce gender differences in pain response, including sociocultural factors, coping mechanisms, and hormonal effects.

Previously, human research has focused primarily on male participants (Al'Absi et al., 1996; Bruehl et al., 1992; France et al., 1991). Men and women differ, however, in both blood pressure and pain sensitivity. For example, men typically have higher blood pressure (McCubbin et al., 1991) and reduced pain sensitivity (Fillingim & Maixner, 1995; Riley, Robinson, Wise, Myers, & Fillingim, 1998) compared with women. Moreover, chronic pain syndromes are more prevalent in women than in men (Unruh, 1996). It is thus imperative to examine potential gender differences in the relation between blood pressure and pain. This study addresses this question in young normotensive men and women exposed to a cold pressor task.

METHOD

Participants

Participants were 55 healthy, normotensive young adults attending Clemson University. They ranged in age from 18 to 29 with a mean age of 19.2 years. Twenty-nine were female (mean age 19.1, range 18–29) and 26 were male (mean age 19.3, range 18–25). Forty-seven were White, 5 were Black, 2 were Asian, and 1 was Hispanic. Female participants at all phases of the menstrual cycle were included. Participants were given course credit in return for participating.

Materials

A Critikon Dinamap Vital Signs Monitor XL (Johnson & Johnson, Tampa, FL) was used to measure heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure.

The McGill Pain Questionnaire (short form; Melzack, 1987) was used to measure pain responses to the cold pressor. It includes a present pain intensity index, a visual analog scale, and a list of pain descriptors rated on a 4-point scale. The present pain intensity index is 6-point scale ranging from 0 (*no pain*) to 5 (*excruciating*). The visual analog scale is another measure of pain intensity anchored by *no pain* and *worst possible pain*. The pain descriptors can be divided into a sensory subscale and an affective subscale, and they can be summed to obtain a total pain score.

Procedure

All experimental sessions were conducted by two experimenters, one male and one female. On arrival in the laboratory, participants read and signed informed consent and answered a personal health history questionnaire. After an accommodation period, they were asked to rest for 10 min while their blood pressure was measured every 2 min. They then were asked to place their dominant hand in a container of water and ice at a temperature of 4 °C. They were instructed to keep their hand in the water for 2 min but were told they could withdraw their hand at any time if it became unbearable. Blood pressure was measured three times during the cold pressor task. To avoid distraction during the stimulus, participants completed the short form of the McGill Pain Questionnaire (Melzack, 1987) after the task was completed. Then participants were asked to sit quietly for a second 10-min resting period while blood pressures were again assessed. After the second resting period, participants were asked to answer some additional questionnaires.

Data Analysis

Blood pressures and heart rate were averaged across experimental periods to obtain pretask resting levels, task levels, and posttask resting levels. Reactivity to the cold pressor was obtained by subtracting the pretask resting levels from the task levels.

One-way analyses of variance (ANOVAs) were used to explore gender differences in resting blood pressures, heart rates, and responses to the McGill Pain Questionnaire as well as reactivity to the cold pressor. Correlations were performed on resting blood pressures and pain ratings for the entire sample, and for men and women separately. Hierarchical regression analyses were performed to test the prediction of pain ratings by resting blood pressure, gender, and the interaction of resting blood pressure and gender.

RESULTS

One-way ANOVAs were performed to examine potential gender differences in resting blood pressure. Pretask resting blood pressures differed significantly between men and women. For example, men had higher resting systolic blood pressure, $F(1, 53) = 68.01$, $p < .001$, and higher mean arterial pressure, $F(1, 53) = 15.83$, $p < .001$, compared with women. Gender differences in systolic blood pressure were within the range previously observed in similar populations (Sherman, Cordova, Wilson, & McCubbin, 1996). There were no observable gender differences in resting diastolic pressure or heart rate. Results for posttask resting blood pressure were comparable.

Most participants were able to tolerate the cold pressor for the 2-min trial; however, 5 women and 2 men were unable to tolerate the cold pressor for the entire period. Deletion of these data did not alter the results of the subsequent analyses, so all analyses are presented with these data included. Gender differences in pain sensitivity, as measured by the McGill Pain Questionnaire, were explored by using one-way ANOVAs. Women reported greater pain than men as measured by the sensory subscale, $F(1, 50) = 4.11$, $p < .05$. Men and women did not differ in pain sensitivity as measured by the present pain intensity index, the visual analog scale,

TABLE 1
Pain Ratings and Resting Blood Pressures by Gender

	Men		*Women*	
	M	*SE*	*M*	*SE*
Present pain intensity index	2.77	0.25	2.72	0.16
Pain intensity visual analog scale	45.12	4.66	49.46	3.81
Total pain score	27.64	1.80	30.96	1.69
Sensory subscale	21.08	1.22	24.59*	1.23
Affective subscale	6.50	0.64	6.24	0.52
Systolic blood pressure	129.10	1.79	107.95*	1.82
Mean arterial pressure	85.05	1.62	76.88*	1.30
Diastolic blood pressure	64.21	1.63	61.70	1.24

*$p < .05$, compared with men.

the affective subscale, or the total pain score. Table 1 provides means and standard errors of blood pressures and pain ratings. Correlations were performed on pretask resting blood pressures and pain ratings, with the entire sample and separately for men and women. These correlations can be found in Table 2. Correlations based on posttask blood pressures were comparable.

Hierarchical multiple regression analyses were performed to predict responses to the McGill Pain Questionnaire. Resting blood pressure and gender were entered in Step 1, and the interaction of gender and resting blood pressure was entered in Step 2. For the present pain intensity index, resting systolic blood pressure was a significant predictor of pain intensity ($\beta = -0.03$, $t[51] = -2.11$, $p < .05$, $r^2 = .08$). Gender and the interaction of gender and resting systolic blood pressure were not significant predictors. When the interaction was added to the model, the change in $r^2 = .001$. For the visual analog scale, resting systolic blood pressure predicted pain intensity ($\beta = -0.70$, $t[48] = -2.23$, $p < .05$, $r^2 = .11$). Gender and the interaction of gender and resting systolic blood pressure were not significant predictors. When the interaction was added to the model, the change in $r^2 = .002$. Resting systolic blood pressure and gender predicted responses on the affective subscale for resting blood pressure ($\beta = -0.53$, $t[51] = -2.65$, $p < .05$) and for gender ($\beta = -1.31$, $t[51] = -2.20$, $p < .05$, $r^2 = .13$). When the interaction of resting blood pressure and gender was added to the model, it was not a significant predictor (change in $r^2 < .001$). Resting systolic blood pressure, gender, and the interaction did not predict responses on the sensory subscale or the total pain score. Gender did not predict responses on the sensory subscale of the McGill Pain

TABLE 2
Correlations Between Resting Blood Pressure and Pain Ratings

	PPI	*VAS*	*Sensory*	*Affect*	*Total*
Entire sample[a]					
Systolic blood pressure	–.25	–.35*	–.35*	–.19	–.32*
Mean arterial pressure	–.26	–.21	–.38*	–.20	–.34*
Diastolic blood pressure	–.26	–.08	–.28*	–.12	–.24
Men[b]					
Systolic blood pressure	–.45*	–.47*	–.19	–.30	–.24
Mean arterial pressure	–.31	–.03	–.35	–.18	–.30
Diastolic blood pressure	–.26	–.07	–.27	–.01	–.18
Women[b]					
Systolic blood pressure	–.31	–.38*	–.26	–.40*	–.32
Mean arterial pressure	–.31	–.35	–.25	–.35	–.29
Diastolic blood pressure	–.29	–.21	–.24	–.28	–.27

Note. PPI = present pain intensity; VAS = visual analog scale.
[a]$N = 55$. [b]$n = 26$. [c]$n = 29$.
*$p < .05$, two-tailed.

Questionnaire, even though men and women differed in their responses to this subscale.

Similar regression analyses with mean arterial pressure and diastolic blood pressure also failed to find significant interactions between gender and resting blood pressure. Simple regression equations with resting systolic blood pressure predicting visual analog pain intensity are shown in Figure 1.

Gender differences in blood pressure reactivity to and recovery from the cold pressor were also examined. Men had larger increases in systolic blood pressure, diastolic blood pressure, and mean arterial pressure during the cold pressor than women (all *p*s < .05). Men also had larger decreases in systolic blood pressure, diastolic blood pressure, and mean arterial pressure than women after the cold pressor (all *p*s < .05). Men had larger posttask resting systolic blood pressure and mean arterial pressure than women (*p*s < .05). Men and women did not differ in posttask resting diastolic blood pressure or heart rate. There were no gender differences in heart rate response to the task. Reactivity to the cold pressor was uncorrelated with pain ratings.

DISCUSSION

In this study we found that resting blood pressure predicts cold pressor pain sensitivity in men and women. Participants with higher blood pressure reported less

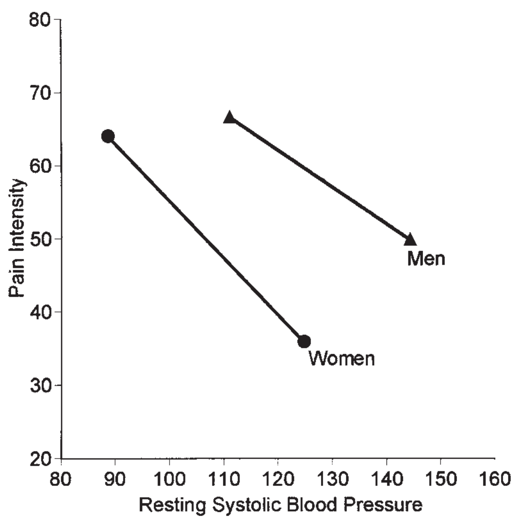

FIGURE 1 Regression lines describing the prediction of pain intensity by resting systolic blood pressure, plotted separately for men and women. The regression equation for men is $y = 122.03 + -0.50x$, and for women $y = 133.03 + -0.78x$.

pain, regardless of gender. We hypothesized that gender differences in resting blood pressure would produce differences in pain sensitivity to the cold pressor task. More surprising, there were few gender differences in ratings of pain intensity. Only one subscale of the McGill Pain Questionnaire was significantly different between men and women. This difference in sensitivity did not translate into differences in the relation between pain sensitivity and resting blood pressure levels. This suggests that the relation between pain and blood pressure is similar in men and women, at least in response to the cold pressor.

The relation between pain sensitivity and blood pressure is robust in studies with male participants (Bruehl et al., 1992; France et al., 1991; Guasti et al., 1995; Sheps et al., 1992). This relationship has also been found in studies that included only female participants (Fillingim, Maixner, Bunting, & Silva, 1998; Fillingim et al., 1997; Pfleeger, Stravena, Fillingim, Maixner, & Girdler, 1997). The studies that have included both male and female participants have occasionally found the relation for women but not men (Bragdon, Light, Girdler, & Maixner, 1997; Nyklicek, Vingerhoets, & Van Heck, 1999) and occasionally for men but not women (Fillingim & Maixner, 1996). Perhaps methodological differences in pain modality or assessment can explain these findings. In this study, absence of gender effects on pain intensity ratings does not preclude potential effects on other pain indexes such as threshold or tolerance. For example, 5 women terminated the 2-min pain trial whereas only 2 men did so. In this study we used only one pain task, to avoid endogenous analgesia evoked by multiple pain trials. However, it is possible that any gender differences in the relation between blood pressure and pain sensitivity are confined to other pain modalities. Additional studies are warranted to examine these issues.

It is possible that the lack of a significant interaction between gender and pain sensitivity reflects statistical power. However, we do not believe this to be the case. For example, when the interaction of gender and resting blood pressure was added to the regression model, the increase in effect size was very small. It is unlikely that even a large increase in sample size would uncover gender differences in this relation. Taken together with the rest of the literature, this indicates that gender differences in blood pressure do not always lead to gender differences in pain responses to cold stimulation. Therefore, we can conclude that blood pressure does not singularly determine gender differences in pain sensitivity using the present methodology. Our findings suggest that factors other than blood pressure can determine gender differences in pain sensitivity.

Studies of this type are particularly important because of the potential role of the relation between blood pressure and pain sensitivity in the etiology of clinical disorders such as hypertension and chronic pain syndromes. For example, the relation between blood pressure and pain sensitivity becomes distorted in chronic pain patients. Bruehl, Burns, and McCubbin (1999) demonstrated that the negative correlation between blood pressure and pain sensitivity observed in nonpain populations changes to a positive correlation with prolonged chronic pain. The greater the chronicity of the chronic pain syndrome, the more positive the observed correlation. In a recent review of the chronic pain literature, Bruehl, McCubbin, and Harden (1999) theorized that this distortion of the relation between blood pressure and pain sensitivity indicates a progressive pathophysiologic alteration in this endogenous pain regulatory mechanism.

Apart from the implications for pain control, this data also may elucidate blood pressure regulatory mechanisms. Dworkin, Filewich, Miller, Craigmyle, and Pickering (1979) suggested that the antinociceptive effects of acute blood pressure elevations could be reinforcing. Although fixed essential hypertension is probably not simply a result of operant conditioning, studies of the relation between pain and blood pressure can give considerable insight into cardiovascular control mechanisms. Nyklicek, Vingerhoets, and Van Heck (1996, 1999) suggested that the effect of blood pressure is not confined to pain sensitivity per se but also may affect appraisal of a broad range of psychologically stressful stimuli. Therefore, the relation between blood pressure and pain sensitivity may index an underlying basic mechanism that integrates the interrelations among pain sensitivity, stress appraisal, and blood pressure control. The potential clinical importance of this mechanism remains to be determined but may extend beyond regulation of pain and blood pressure to a broader role in general affect regulation.

In this study we found no difference between men and women in the relation between blood pressure and cold pressor pain sensitivity. Men and women did differ in their resting blood pressure levels, but blood pressure did not interact with gender to affect pain sensitivity. These findings suggest that the relation between blood pressure and pain sensitivity may be similar in men and women.

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