Psychosomatic Factors in Borderline Hypertensive Subjects and Offspring of Hypertensive Parents

Charles Perini, Franco B. Müller, Udo Rauchfleisch, Raymond Battegay, Viktor Hobi, and Fritz R. Bühler

Psychosomatic factors, sympathoneural and sympathoadrenal as well as cardiovascular mechanisms, were studied in 24 patients 18–24 years of age with borderline hypertension, 50 age-matched normotensive offspring of hypertensive parents, and 49 controls with no family history of hypertension. They were compared by projective and questionnaire-based psychological tests and their circulatory and neurohormonal reactivity to mental (Stroop color-word conflict test and arithmetic test) and physical stressors (orthostasis and bicycle ergometry test) were measured. Borderline hypertensive subjects externalized aggression less (p<0.05) but internalized it more (p<0.05) and were more submissive (p<0.05) when compared with controls. Offspring of hypertensive parents showed a similar but weaker pattern. Both risk groups reported more positive interactions with their parents (genetic risk subjects versus controls, p<0.05; borderline hypertensive patients versus controls, p=0.08) and had higher state-anxiety levels (p<0.05). There were more subjective symptoms of β-adrenergic receptor-mediated functions (e.g., tachycardia, tremor) in borderline hypertensive subjects and offspring of hypertensive parents, elevated heart rates (analysis of repeated measures, p<0.001), and enhanced plasma norepinephrine concentrations (p<0.05) when compared with controls. These findings in subjects at risk for the development of hypertension suggest that psychosomatic factors and sympathetic overactivity are involved in the early phase of hypertension. (Hypertension 1990;16:627–634)

Essential hypertension is often considered to have a psychosomatic component, but the evidence to date is rather limited. The suppression of hostility was thought to be an important characteristic in the profile of hypertensive subjects, although some investigators have questioned this. Neurogenically mediated excessive responsiveness to stressful stimuli has been proposed as a pathophysiological mechanism. More frequent, larger, and longer-lasting pressor responses result in a pressure-related impairment of baroreceptor reflexes followed by a resetting, or lead to structural adaptive changes in the resistance vessels. In addition, enhanced sympathetic nervous system activity may result in increases in cardiac output, vascular resistance, and sodium and water retention and thereby elevated levels of blood pressure.

In accepting a psychosomatic approach to the pathogenesis of hypertension, the psychosomatic factor must be present well before the development of high blood pressure. We therefore investigated risk groups (i.e., patients with borderline hypertension and normotensive subjects with a family history of hypertension) rather than established hypertensive patients. Psychological characteristics were assessed by projective and questionnaire-based psychological tests in an endeavour to differentiate the above risk groups from a control population with a low risk of hypertension. Responses to stressors (i.e., cognitive tasks and physical exercise) were compared by measuring cardiovascular and biochemical stress markers.

Methods

Subjects

Of the 123 subjects, 18–24 years old and of both sexes, all were Caucasian: Twenty-four were consecutive untreated outpatients with borderline hypertension (15 with and nine without a family history of
hypertension). Patients were considered borderline hypertensive if in the preceding year a minimum of two casual blood pressure measurements were 140/90 mm Hg or greater (Korotkoff phases I and V) and two measurements were less than 140/90 mm Hg, but none exceeded 160/100 mm Hg. Secondary forms of hypertension were excluded by medical history, physical examination, and appropriate biochemical tests. Fifty were normotensive (blood pressures less than 140/90 mm Hg on three measurements) subjects with a positive family history of hypertension. They consisted of the progeny of patients from our outpatient clinic. Forty-nine were normotensive controls with no family history of hypertension. They were healthy volunteers recruited by local advertisements and were matched with the other groups in family socioeconomic backgrounds, as previously defined.

Study Design

In a first session, psychological tests and questionnaires were administered, and measurements of weight, height, maximal physical work capacity (PWC\textsubscript{max}) on a bicycle ergometer as well as two seated and two supine blood pressure measurements (automatic Tonoprint, Speidel and Keller, Jungingen, FRG) were obtained. In the experimental session, stress stimuli were applied and blood pressure, heart rate, and plasma catecholamines were measured. On the day previous to the experimental session, a 24-hour urine collection was taken and measured for sodium excretion as an index of dietary sodium intake. All subjects were tested between 10:00 AM and noon. They were instructed to abstain from smoking, caffeine, and alcohol for at least 12 hours before testing. Present anxiety (state-anxiety) was assessed with the State-Trait Anxiety Inventory. After a venous catheter was inserted into an antecubital vein, the blood pressure cuff as well as electrodes for the electrocardiogram were attached.

The experimental session consisted of 10 periods of testing and a total of 113 minutes in a quiet, air-conditioned room: 1) pretest baseline (20 minutes), 2) familiarization with the Stroop color-word conflict test (2 minutes), 3) resting period (4 minutes), 4) Stroop test (8 minutes), 5) resting period (16 minutes), 6) mental arithmetic (4 minutes), 7) supine baseline (20 minutes), 8) orthostasis (4 minutes), 9) bicycle ergometry (25%, 50%, and 75% of PWC\textsubscript{max}; each workload lasting 5 minutes), 10) recovery period (20 minutes).

Subjects were comfortably seated during periods 1–6 and 10. Blood pressures were measured automatically at 2-minute intervals, heart rates were monitored continuously, and 10 blood samples were taken. To calculate cardiovascular reactivity to mental stressors, stress levels were subtracted from baseline values as defined by the average of measurements between minute 4 to 12 and minute 40 to 48, respectively.

The protocol was approved by the Hospital Ethics Committee, and subjects gave their informed consent.

Psychological Tests and Questionnaires

The newly standardized version\textsuperscript{13} of the Rosenzweig Picture-Frustration test\textsuperscript{12} is a projective method to assess reactions to everyday frustrating situations that might otherwise be masked by the subject's psychological defenses. The test consists of 24 cartoons each displaying two or more persons in various situations, one of whom frustrates or describes the frustration of someone else. The subject is expected to spontaneously write a response in the blank balloon in the cartoon. Standard values (stanines) adjusted for age and sex have been evaluated in our local population.\textsuperscript{11}

The Giessen test\textsuperscript{13} was used to measure personality traits and social behavior. Subjects are required to rate themselves on a seven-point scale ranging from −3 to +3 on 40 items, each describing two extreme traits or reactions. Six scales are expressed as scores with a mean of 50 and standard deviation of 10: unpopular—popular, domineering—submissive, poor self-control—good self control, hypomanic—depressive, extroverted—introverted, gregarious—ungregarious. This test can be applied both as description of self and as description of the self-ideal.

The German translation\textsuperscript{14} of the State-Trait Anxiety Inventory\textsuperscript{10} measures the subject's current anxiety level and tendency toward anxiety. Each scale consists of 20 statements requesting subjects to describe their particular feelings at a given instance or how they generally feel on a four-point scale. For trait-anxiety, stanine values adjusted for age and sex have been expressed.

Family upbringing scale\textsuperscript{15} is a 20-item questionnaire to gauge interaction between subjects and their parents in childhood. Standard values have been expressed as stanines adjusted for age or sex.

In the analogue scales to assess physical and psychological complaints, 16 subjects were asked to define their responses over the preceding 6 months to 49 items rated from "nonexistent" to "unbearable" on a 100 mm horizontal line.

Cognitive Stress Tests

Each test was preceded by written instructions provided 2 minutes beforehand.

Stroop color-word conflict test: In an altered version of Bjorkvall's modification\textsuperscript{17} of Stroop's test,\textsuperscript{18} four color words (red, blue, green, or yellow) were projected in alternating nonmatching colors on a white wall. Subjects were further distracted by simultaneously hearing the name of yet a third incongruous color. Subjects were requested to 1) name the color seen, 2) name the color written, and 3) name the color heard.

In the mental arithmetic test, pairs of calculations (e.g., 8−2+3=7 and 9+1−7=7) were projected for 5–8 seconds on each of 30 slides. The difference between the two sums was considered the correct result.
### TABLE 1. Demographic and Physical Group Characteristics

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th>Borderline hypertensive group (n=24)</th>
<th>Offspring of hypertensive parents (n=50)</th>
<th>Control group (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>22±2</td>
<td>19±2</td>
<td>21±2</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>males</td>
<td>18</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>females</td>
<td>6</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>2.3±1.0</td>
<td>2.7±1.1</td>
<td>2.4±1.1</td>
</tr>
<tr>
<td>Seated SBP (mm Hg)</td>
<td>140.8±10.1*</td>
<td>125.4±9.3</td>
<td>122.3±9.6</td>
</tr>
<tr>
<td>Seated DBP (mm Hg)</td>
<td>86.8±11.6†</td>
<td>76.3±11.9</td>
<td>78.5±7.5</td>
</tr>
<tr>
<td>Supine SBP (mm Hg)</td>
<td>131.8±11.3*</td>
<td>115.6±8.5‡</td>
<td>110.9±8.7</td>
</tr>
<tr>
<td>Supine DBP (mm Hg)</td>
<td>79.3±9.2*</td>
<td>72.0±7.7</td>
<td>68.8±9.4</td>
</tr>
<tr>
<td>Quetelet index (wt/ht²×100)</td>
<td>2.3±0.3*</td>
<td>2.1±0.2</td>
<td>2.1±0.2</td>
</tr>
<tr>
<td>Sodium excretion (mmol/24 hrs)</td>
<td>197.0±69.1§</td>
<td>156.5±63.6</td>
<td>157.5±72.1</td>
</tr>
<tr>
<td>Maximal work capacity (watt)</td>
<td>231.3±70.8</td>
<td>203.0±58.8</td>
<td>221.9±67.2</td>
</tr>
</tbody>
</table>

Values are mean±SD.

* p<0.001 in borderline hypertensive versus genetic risk versus control group.
† p<0.01 in borderline hypertensive versus genetic risk versus control group.
‡ p<0.01 in genetic risk versus control group.
§ p<0.05 in borderline hypertensive versus genetic risk versus control group.

### Blood Samples

Ten blood samples were taken and plasma epinephrine (PE) as well as norepinephrine (PNE) were measured as follows: 5 minutes before and immediately before the Stroop test familiarization phase; before and during the last 30 seconds of the Stroop test; before and during mental arithmetic; after supine rest as well as during orthostasis; during 75% of PWQmax workload and after 20 minutes resting in the seated position. Samples were collected into chilled glass tubes containing lithium heparin, placed on ice, centrifuged immediately after the session and the plasmas frozen at -70°C.

Epinephrine and norepinephrine were determined using a radioenzymatic method.

### Statistics

Statistical analyses were carried out by means of the Statistical Package for the Social Sciences. Analyses of variance and two-tailed Student's t tests were used to compare differences of means. Two-factorial repeated-measure analyses of variance were performed on all circulatory and biochemical data with group and sex as independent variables. Correlation coefficients were calculated by Pearson product-moment or Spearman rank-order procedures where appropriate. Results were expressed as mean±SD (or ±SEM), and values of p<0.05 were regarded as significant.

### Results

#### Subject Characteristics

Borderline hypertensive subjects had higher blood pressures in the first session (mean of two measurements after 5 minutes of seated or supine rest), were heavier, and excreted more urinary sodium as compared with the offspring of hypertensive parents and control subjects (Table 1). There were no differences among the groups in either socioeconomic level or individual maximal work capacity.

#### Questionnaires and Psychological Tests

In the Rosenzweig Picture-Frustration test (Figure 1) the borderline hypertensive group externalized (variable E) their aggressions significantly less, and internalized (variable autoaggression and Cat. I, which includes autoaggression as well as guilt feelings) them more as compared with the control group. This resulted in a significantly smaller quotient of "externalized/internalized aggression" (E/I). The offspring of hypertensive parents exhibited a similar but weaker pattern. When compared with controls, the differences of the variable Cat. I and the quotient E/I reached borderline significance (p=0.06 and p=0.057, respectively).

Because the Giessen test has no age- and sex-adjusted standard values, carefully age- and sex-matched subjects, 24 in each group, were compared (Figure 2). The borderline hypertensive group described themselves as significantly more submissive than the control population. This scale correlated significantly with the variable E (externalized aggressions) of the Rosenzweig test (r=-0.57, p<0.01) in the borderline hypertensive group. Describing their self-ideal, the borderline hypertensive group wished to be more self-controlled as compared with the control group (scale "self-control": 27.0±3.5 versus 24.4±4.2, p<0.05).

In the State-Trait Anxiety Inventory, trait anxiety expressed as stanine values was similar among the three groups (between 4.95 and 4.84). Comparing raw values of state-anxiety in age- and sex-matched subjects.
groups, the borderline hypertensive group (37.75 ± 6.98) as well as the offspring of hypertensive parents (36.16 ± 5.59) were significantly more anxious than the control group (32.95 ± 5.17, p < 0.05). The correlation between state-anxiety and the Rosenzweig variable "externalized aggression" nearly reached significance (r = -0.30, p = 0.08) in the borderline hypertensive group.

Family upbringing scale: Both the borderline hypertensive group and the offspring of hypertensives had lower mean stanine values (3.87 ± 1.6 and 3.92 ± 1.4, respectively) than the control group (4.65 ± 1.9) (borderline hypertensive group versus controls, p = 0.08; offspring of hypertensive parents versus controls, p < 0.05). The lower stanine value found in both the borderline hypertensive and the genetic risk group reflects a more favorable upbringing style and improved parent–child interaction compared with controls.

In the analogue scales to assess physical and psychological complaints (Table 2), the borderline hypertensive group reported significantly more symptoms reflecting sympathetic overactivity such as tachycardia and hand tremor, as well as less drowsiness compared with controls. Tachycardia and tremor were also more often reported in offspring of hypertensive parents than in the control group.

**Group Differences in Blood Pressure**

Repeated-measures analyses of variance (3 × 2, group × sex) revealed significant differences between groups and sex in systolic (group, F = 26.54, p < 0.001; sex, F = 10.75, p < 0.001) and in diastolic blood pressure levels (group, F = 9.64, p < 0.001; sex, F = 2.05, p < 0.01; group × sex, F = 4.43, p < 0.001). As illustrated in Figure 3, the borderline hypertensive group had consistently higher systolic and diastolic blood pressures than the control group (F = 44.31, p < 0.001 and F = 18.60, p < 0.001) and offspring of hypertensive parents (F = 38.61, p < 0.001 and F = 10.15, p < 0.001). Differences in systolic pressure were least salient after bicycle ergometry. In offspring of hypertensive parents, blood pressure levels were slightly but significantly higher compared with those of controls (systolic blood pressure, F = 3.20, p < 0.001; diastolic blood pressure, F = 2.09, p < 0.01).

Men exhibited higher systolic blood pressure levels than women (p < 0.05 or better). In contrast, male and female offspring of hypertensive parents and the control group had similar diastolic blood pressure, whereas in the borderline hypertensive group, the women had higher mean blood pressure levels than the men.

No group differences in blood pressure reactivity to mental or physical stressors were observed.
TABLE 2. Analogue Scales of Physical and Psychological Complaints

<table>
<thead>
<tr>
<th>Complaints</th>
<th>Borderline hypertensive group (n=24)</th>
<th>Offspring of hypertensive parents (n=50)</th>
<th>Control group (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tremor</td>
<td>12.8±24.5*</td>
<td>10.2±14.2</td>
<td>4.4±8.8</td>
</tr>
<tr>
<td>Weight gain</td>
<td>7.4±16.7*</td>
<td>3.0±7.9</td>
<td>1.6±4.4</td>
</tr>
<tr>
<td>Muscle cramps</td>
<td>1.2±3.4†</td>
<td>7.3±16.3‡</td>
<td>2.3±5.8</td>
</tr>
<tr>
<td>Stomachache</td>
<td>1.7±5.4†</td>
<td>7.3±12.9‡</td>
<td>2.7±7.0</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>12.1±17.4*</td>
<td>10.1±14.4†</td>
<td>2.6±5.5</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>7.8±13.2†</td>
<td>20.4±19.5</td>
<td>18.6±17.4</td>
</tr>
<tr>
<td>Disequilibrium</td>
<td>1.7±5.1</td>
<td>3.9±9.4‡</td>
<td>0.5±2.5</td>
</tr>
</tbody>
</table>

Values are mean±SD of the scales differentiating the three groups.
* p<0.05 in borderline hypertensive versus control group.
† p<0.05 in borderline hypertensive versus genetic risk group.
‡ p<0.05 in genetic risk versus control group.

three groups responded with significant but similar changes in systolic and diastolic blood pressure: average means were 11.1±7.1 and 8.8±8.7 mm Hg during the Stroop test, 7.6±7.1 and 5.9±8.7 mm Hg during mental arithmetic, -4.1±10.2 and 2.4±9.8 mm Hg during orthostasis, and 37.5±15.9 and -12.7±12.9 mm Hg during bicycle ergometry.

Group Differences in Heart Rate

For heart rate, a 3×2 (group×sex) analysis of repeated measures yielded significant differences for group (F=4.66, p<0.001) and sex (F=10.62, p<0.001). Heart rate was higher in the borderline hypertensive group than in both normotensive groups as depicted in Figure 4 (borderline hypertensive group versus controls, F=9.33, p<0.001; borderline hypertensive group versus offspring of hypertensive parents, F=2.09, p<0.01). However, at the end of bicycle ergometry heart rate tended to be lower in the borderline hypertensive group than in the other groups. Offspring of hypertensive parents also had higher heart rates as compared with controls (F=3.8, p<0.001).

Women demonstrated significantly higher heart rate levels at baseline and during stressors than men, whereby these findings were more pronounced in the borderline hypertensive group.

Heart rate increases were comparable in all groups, with average changes of 19.5±9.9 beats/min during the Stroop test, 5.0±7.0 during mental arithmetic, 16.0±7.9 during orthostasis, as well as 91.0±15.7 during bicycle ergometry. There were no gender differences in heart rate responses.

Group Differences in Plasma Catecholamines

A repeated-measures analysis of variance revealed a difference in PNE among the groups (F=3.05, p<0.001) but not for sex (F=1.45, p>0.10). The borderline hypertensive group had higher PNE con-

![Figure 3. Graph showing systolic and diastolic blood pressures at rest and during the color-word conflict test (CWCT), mental arithmetic (MA), orthostasis (OR), and bicycle ergometry (ERG) in borderline hypertensive patients ■, offspring of hypertensive parents ●, and normotensive controls ○.](http://hyper.ahajournals.org/doi/abs/10.1161/HYPERTENSIONAHA.106.047164?journalCode=hyp)
centrations than the offspring of hypertensive parents and the control group ($F=1.89, p<0.05$ and $F=2.18, p<0.05$, respectively) throughout the test procedure. Differences were observed before the Stroop test familiarization phase and in the recovery phase after physical work (Table 3). Offspring of hypertensive parents also had higher PNE concentrations than controls in analysis of repeated measures ($F=1.88, p<0.05$), but no further differences were observed. PE was comparable in all three groups (Table 3) but was consistently higher in men than in women ($F=8.66, p<0.001$).

**Discussion**

Psychological, sympathoneural, and cardiovascular response differences were found between borderline hypertensive subjects and normotensive children of hypertensive parents as compared with normotensive subjects with no family history of hypertension. Borderline hypertensive and genetic risk subjects were characterized by internalized aggressions, a desire for self-control, a high level of situation-specific anxiety, and more frequently reported episodes of palpitation and hand tremor. Subjects of both risk groups for hypertension had a more favorable upbringing and interaction with their parents. Heart rate, blood pressure, and plasma norepinephrine concentrations were higher in the borderline hypertensive group and offspring of hypertensive parents as compared with the normotensive controls, reflecting increased risk for future hypertension development.8-21,22

**Table 3. Plasma Epinephrine and Norepinephrine Concentrations at Rest, Before, and During Mental and Physical Stressors**

<table>
<thead>
<tr>
<th>Blood sample withdrawal</th>
<th>Borderline hypertensive group ($n=24$)</th>
<th>Offspring of hypertensive parents ($n=50$)</th>
<th>Control group ($n=49$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PE (pg/mL)</td>
<td>PNE (pg/mL)</td>
<td>PE (pg/mL)</td>
</tr>
<tr>
<td>During anticipation</td>
<td>46±25</td>
<td>298±104</td>
<td>43±27</td>
</tr>
<tr>
<td>Before familiarization with CWCT</td>
<td>60±34</td>
<td>297±97*</td>
<td>57±39</td>
</tr>
<tr>
<td>Before CWCT</td>
<td>43±17</td>
<td>297±95</td>
<td>45±24</td>
</tr>
<tr>
<td>During CWCT</td>
<td>49±24</td>
<td>302±84</td>
<td>45±20</td>
</tr>
<tr>
<td>Before MA</td>
<td>46±24</td>
<td>296±94</td>
<td>42±22</td>
</tr>
<tr>
<td>During MA</td>
<td>57±27</td>
<td>302±94</td>
<td>53±24</td>
</tr>
<tr>
<td>After 20 minutes of supine rest</td>
<td>33±19</td>
<td>239±95</td>
<td>26±15</td>
</tr>
<tr>
<td>During OR</td>
<td>41±21</td>
<td>379±138</td>
<td>33±15</td>
</tr>
<tr>
<td>During ERG</td>
<td>107±43</td>
<td>1010±430</td>
<td>99±52</td>
</tr>
<tr>
<td>After 20 minutes of seated rest</td>
<td>58±28</td>
<td>423±172*</td>
<td>53±26</td>
</tr>
</tbody>
</table>

Values are mean±SD in picograms per milliliter. PE, plasma epinephrine; PNE, plasma norepinephrine; CWCT, color-word conflict test; MA, mental arithmetic test; OR, orthostasis test; ERG, bicycle ergometry test.

*p<0.05 in borderline hypertensive versus control group.

fp<0.01 in borderline hypertensive versus genetic risk versus control group.
heart rate levels were even lower in borderline hypertensive subjects. The combination of an increased sympathetic and a decreased parasympathetic tone indicates that the central nervous system is involved. Accordingly, psychosomatic influences may be responsible for the autonomic abnormalities in borderline hypertension.

Suppressed aggression has been related to a hyperdynamic cardiovascular regulation in borderline hypertensive subjects and offspring of hypertensive parents as well as an increased adrenergic reactivity in borderline hypertensive patients. It has been found especially in high renin established hypertension and borderline hypertension. Neurogenic mechanisms have been shown to be responsible for blood pressure elevation in patients with high renin borderline hypertension and mild elevated essential hypertension.

The results of the present study suggest that psychosomatic factors mediated by the sympathetic nervous system can be discerned in patients with borderline hypertension as well as in normotensive offspring of hypertensive parents. Previous work by others indicates that suppressed aggression relates to patients with essential hypertension, particularly of the high renin type.

References


Key Words: borderline hypertension • genetic hypertension • risk factors • stress
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Hypertension. 1990;16:627-634
doi: 10.1161/01.HYP.16.6.627

Hypertension is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1990 American Heart Association, Inc. All rights reserved.
Print ISSN: 0194-911X. Online ISSN: 1524-4563

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http://hyper.ahajournals.org/content/16/6/627