Perceived Job Stress but not Individual Cardiovascular Reactivity to Stress Is Related to Higher Blood Pressure at Work

Jean Pierre Fauvel, Pierre Quelin, Michel Ducher, Hantanirina Rakotomalala, Maurice Laville

Abstract—Psychological stress has been reported to be related to higher blood pressure (BP) and unfavorable cardiovascular profile. However, because of the complexity of personal stress management, a multilevel stress measurement strategy is needed. The aim of this cross-sectional study was to analyze the respective influences of the subjective perception of professional strain (high demand and low latitude) and cardiovascular reactivity to a stress test (Stroop stress test) on BP. Worksite BP was measured in 303 healthy normotensive subjects, 18 to 55 years of age, who worked in the same chemical company. In a subset of 70 randomly selected subjects, 24-hour ambulatory BP was performed to assess BP during working hours. The 20% of subjects who reported the highest job strain (high-strain group) or the highest BP stress reactivity (high-responder group) were compared with the remaining subjects (80%) (non–high-strain or low-responder groups). Subjects who submitted to the highest job strain had significantly higher ambulatory diastolic BP (4.5 mm Hg, \( P = 0.015 \)) during only working hours, whereas BP was similar during the remaining hours. Worksite BP and stress cardiovascular reactivity were similar between job strain groups. BP stress reactivity did not influence worksite and ambulatory BP. Spontaneous BP variability assessed by standard deviation and spectral analysis was equivalent between complementary groups. Prevalence of microalbuminuria was significantly higher in the high-responder group (8.2% versus 2.5% in low responders) and only slightly higher in the high-strain group (6.2% versus 3.2% in non–high strain). Potential confounding factors, such as age, gender, alcohol consumption, salt intake, body mass index, and occupation, which were equivalent between groups, did not interfere with our results. Our study quantifies high-professional strain effects on BP levels that appear to be higher only during the working period and to be independent from spontaneous BP variability and stress BP reactivity. (Hypertension. 2001;38:71-75.)

Key Words: stress ▪ blood pressure, ambulatory ▪ job strain ▪ microalbuminuria

The term “stress” is widely used by behavioral and biomedical scientists, but there is no consensus as to the scientifically precise definition of the concept. Selye’s basic concept of an organism’s response to stress, the “general adaptation syndrome,” infers that any kind of environmental strain results in a common defensive reaction that is the result of sympathetic activation leading to catecholamine release. However, physiological studies proved that the hormone response (epinephrine, norepinephrine, and steroids) may vary among the nature of stimulus. More recently, the psychological perception of stress has been emphasized because stress perception may differ among individuals. Psychological stressors are filtered by cognitive appraisal mechanisms before causing a biological response; thus, for the same strain, individual effects may differ. Because a multilevel measurement strategy is needed to quantify stress, in this study we have focused our attention on 2 different stress quantifications. The first quantification scored the integrated perception of professional strain using the questionnaire developed by Karasek et al. In the second quantification, the same standardized strain (Stroop stress test) was applied to each subject and the subject’s cardiovascular reactivity was registered. The aim of our study was to evaluate the potential influence of stress (cardiovascular reactivity and quantification of professional strain) on casual blood pressure (BP) measured at the worksite and on ambulatory BP measured during a working day.

Methods

Participants

The study was conducted on 473 subjects between 18 and 55 years of age who were employed full time in a chemical company. Among the eligible subjects, 370 volunteered to participate to the study. Out of 370 subjects, 303 normotensive (BP <140/90 mm Hg) subjects (235 men and 68 women) were included if their dipstick urinalysis was within normal limits and if they were free of any current medication that could interfere with BP regulation. The protocol was

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approved by the Lyons’ Ethic Committee for Protection of Volunteers in Biomedical Research, and written informed consent was obtained from each subject.

**Routine Clinical Examination**

At the annual working visit, subjects were given a routine medical examination that included a full history, a physical examination, a body mass index (BMI) determination, and an assessment of alcohol intake. Worksite BP was measured 3 times at the worksite with a mercury sphygmomanometer after the subject had rested 5 minutes in a reclining position. The average of the last 2 (of 3) BP measurements was considered (Table 1). Alcohol intake was ranked in 5 levels by interview: <1 drink per week, <1 drink per day, 1 to 2 drinks per day, 3 to 4 drinks per day, and >4 drinks per day.

**Questionnaire**

The self-administered questionnaire was a French version of the job content’s questionnaire including, as recommended by Karasek et al,3 18 items to assess job demand and job decision latitude. Each content’s questionnaire including, as recommended by Karasek et al,3 18 items to assess job demand and job decision latitude. Each item was rated on a 4-point scale that ranged from “strongly disagree” to “strongly agree.” This French version has been validated a posteriori by Larocque et al5 in white and blue collar workers of the Canadian general population. The 20% of the subjects who reported the highest job demand and the lowest job decision latitude was considered as the high-strain (HS) group and compared with the remaining subjects (non–high-strain [NHS] group).6

**Mental Stress**

Mental stress was induced by a computerized version of Stroop’s color conflict test (CWT).7 Successive series of 4 color words written in incongruent colors appeared in random order on the screen. The subjects had to type the color of the word on selected keys from the keyboard. An audio signal was provoked if a wrong response was made. The examiner encouraged subjects to perform the stress test at their maximum speed, but the examiner kept an emotionally neutral attitude throughout the test.

**Finapres Recordings**

Rest and stress BP were recorded using a Finapres device (model 2300, Ohmeda). The cuff was wrapped around the forefinger of the nondominant arm relying on a table, in which the level was adjusted to obtain <5 mm Hg difference with the previously determined BP (mercury sphygmomanometer). The equipped arm was held in the same position throughout the procedure. After 2 minutes of familiarization, the automatic calibration was switched off and the BP was recorded for 15 minutes. Signal acquisition and data processing were previously described.8 In brief, the analog output from the Finapres was connected to an analog-to-digital converter to perform data acquisition, storage, and analysis. Finapres signals were sampled at a rate of 100 Hz with 8 precision bits. Our own algorithm to detect systolic BP (SBP) and diastolic BP (DBP) is accurate enough to compute heart rate so that ECG signal recording was not necessary. Aberrant beats, that never exceeded 10%, were >5% in only 10% of the subjects. The beats always concerned DBP determination, never SBP determination.8 Each patient was recorded during 10 minutes at rest and during 5 minutes of mental stress. Data processing was performed on a 4-minute recording both at rest and during stress after a delay of 1 minute and of 30 seconds, respectively. Rest and stress data were obtained during these two 4-minute periods. Frequency domain analyses of heart rate and SBP oscillations were performed by spectral analysis using the Fast Fourier transformation (FFT) algorithm. The FFT was applied on 342 points from a 4-minute recording resampled at 1.4286 Hz (0.7 seconds) and completed to 512 points by the zero-padding technique to enhance the spectral resolution (1.7 mHz).8 BP variability was expressed as standard deviation and power spectra in the low-frequency band (0.07 to 0.14 Hz) and in the high-frequency band (0.14 to 0.40 Hz).

**Ambulatory BP Monitoring**

Out of 100 randomly selected subjects, 87 subjects volunteered to wear an ambulatory BP monitor (ABPM; SpaceLabs 90207) for 24 hours during a regular workday. Out of the 87 selected volunteers, 70 ambulatory BP monitorings were performed in the 303 included subjects. BP was measured at a 15-minute interval between 6:00 AM to 10:00 PM and at a 30-minute interval during the remaining hours. The diary information allowed the calculation of average working, sleeping, and waking BP. The method used to validate these readings has been previously described.9,10

**Urinalysis**

Twenty-four-hour urine collection for electrolyte, creatinine, urea, and albuminuria excretion was performed at the worksite and was available in 293 out of the 303 subjects. Subjects were asked to void their bladder for dipstick urinalysis and then to collect their urine for 24 hours. A diary allowed the precise adjustment of urinary excretion data for 24 hours. Urine collection for <23 hours and >25 hours were discarded. Albuminuria was measured by an immunoturbidimetric method (threshold of detection, 6 mg/L). Subjects whose urinary albumin excretion rate (UAER) was >30 mg/24 hours were considered microalbuminuric.

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**Table 1. Main Characteristics of the 4 Groups Classified by Their Job Strain and Their SBP Response to Mental Stress**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High Strain</th>
<th>Non–High Strain</th>
<th>High Responders</th>
<th>Low Responders</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>61 (14)</td>
<td>220 (56)</td>
<td>61 (14)</td>
<td>235 (56)</td>
</tr>
<tr>
<td>Age, y</td>
<td>35±2 (35±3)</td>
<td>38±1 (36±1)</td>
<td>37±1 (39±3)</td>
<td>38±1 (35±1)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>25±1 (24±1)</td>
<td>25±1 (25±1)</td>
<td>25±1 (26±1)</td>
<td>25±1 (24±1)</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>124±1 (124±1)</td>
<td>125±1 (126±1)</td>
<td>126±1 (126±1)</td>
<td>125±1 (126±1)</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>77±1 (79±1)</td>
<td>78±1 (77±1)</td>
<td>78±1 (78±1)</td>
<td>78±1 (78±1)</td>
</tr>
<tr>
<td>HR, bpm</td>
<td>63±1 (60±2)</td>
<td>63±1 (62±1)</td>
<td>62.8±8 (63±1)</td>
<td>63±1 (62±1)</td>
</tr>
<tr>
<td>Sodium, g/24 hours</td>
<td>9.4±0.4 (9.5±1)</td>
<td>9.8±0.2 (10.1±0.5)</td>
<td>9.6±0.5 (10.6±1)</td>
<td>9.6±0.2 (9.6±1)</td>
</tr>
<tr>
<td>Alcohol mean score</td>
<td>1.8 (1.6)</td>
<td>2.1 (2.1)</td>
<td>2.0 (1.8)</td>
<td>2.1 (2.1)</td>
</tr>
<tr>
<td>ΔSBP, mm Hg</td>
<td>20.1±1.6</td>
<td>22.3±0.8</td>
<td>39.7±0.8*</td>
<td>17.2±0.6</td>
</tr>
<tr>
<td>ΔDBP, mm Hg</td>
<td>9.9±0.7</td>
<td>10.0±0.4</td>
<td>14.8±0.6*</td>
<td>8.6±0.3</td>
</tr>
<tr>
<td>ΔHR, bpm</td>
<td>9.5±1.2*</td>
<td>7.5±0.5</td>
<td>11.2±1.0*</td>
<td>6.8±0.5</td>
</tr>
</tbody>
</table>

Mean values of randomized subgroups who wore an ABPM are given in parentheses. Values are given as mean±SEM. Δ indicates stress-induced variation. *P<0.05 between complementary groups (HS vs NHS or HL vs LR).
Statistical Analysis

The calculated number of subjects to observe a significant ($P<0.05$) difference in DBP between the 2 job strain groups (20% in the HS group) of 3 mm Hg (standard deviation 7 mm Hg) with a power of 90% was close to 300 subjects. Data are expressed as mean±SEM in text, tables, and figures. Mean values were compared between complementary groups (HS versus NHS and high responder [HR] versus low responder [LR]) using ANCOVA with gender, age, alcohol intake, BMI, occupation, and sodium intake as intersubject factors. Response to stress test was analyzed as change from baseline. Prevalence of microalbuminuria was compared between groups using a $\chi^2$ test. $P<0.05$ was considered significant.

Results

To separate the 20% of the subjects who had the lowest latitude and the highest demand, cutoff values were <36 and >28, respectively. Thus, from the 303 included subjects, 61 individuals (20.1%, 54 men and 7 women) were considered having the highest strain (HS group) and were compared with the 220 remaining subjects (NHS group, 202 men and 18 women). In 22 subjects, the questionnaire analysis could not be performed (missing responses, forgotten questionnaire, or refused to respond). Similarly, the 61 subjects with the highest SBP reactivity to the stress test (HRs, 58 men and 3 women) were compared with the remaining subjects (LRs, 213 men and 22 women; 7 were missing the Finapres BP). The main characteristics of the subjects of the complementary groups were similar to that shown in Table 1. Worksite BP and stress reactivity did not differ between the HS and NHS groups (Table 1).

Mean clinical characteristics of randomized samples were similar to their respective entire groups (Table 1). Ambulatory BP measurements were performed in 14 HS and 56 NHS group subjects. During working hours, SBP was slightly higher in the HS group whereas DBP was significantly higher (Figure). During the remaining hours, BP was similar between groups (Figure). Heart rate was similar in the HS and NHS groups (63±1 versus 63±1 bpm). Suspected confounding factors (age, gender, BMI, alcohol intake, and sodium intake) were not different between groups, and ANCOVA controlling the above variables provided similar findings.

Fortunately, randomly selected patients who wore ABPMs were 14 in the HR group and 56 in the LR group. As shown in the Figure, stress reactivity did not influence neither ambulatory BP values during 24-hour, working, and nonworking periods nor heart rate values (62±8 versus 63±1 bpm in the HR versus LR groups).

SBP and heart rate variabilities expressed both as standard deviation and as spectral parameters were not different between complementary groups at rest and during stress (Table 2).

Among the whole group of normotensive subjects, the prevalence of microalbuminuria was 3.7%. The prevalence of microalbuminuria was significantly higher in the HR group (8.2% versus 2.5% in the LR group; $P<0.05$), whereas the higher prevalence in the HS group (6.6% versus 3.2% in the NHS group) was not significant.

Discussion

Work is typically associated with increased BP\textsuperscript{10} and the pattern may be enhanced when the work stress is high. However, demanding jobs are not necessary stressful if one can organize the job to best meet the workload. Job characteristics, such as job demands and decision latitude, may also contribute to work-related stress and Karasek et al\textsuperscript{3} hypothesized that the job most likely to generate distress combined the highest demand with the lowest control. However, the hypothesis that high professional strain could be related to a higher BP during working hours remains controversial.\textsuperscript{11–16} Furthermore, a higher BP at work may be due to an exaggerated BP response to similar strains.\textsuperscript{17–20} Previous studies did not provide a clear picture of the influence of potentially stress-related factors on BP in normotensive subjects. Thus, the present study was conducted to examine the putative importance of subjective self-reported job strain and objective stress-induced response on BP, with a special focus on working ambulatory BP. Our main result is that high job strain is associated with a higher DBP during working hours only, irrespective of other potential BP-related factors and of BP reactivity to a stress test. Categorization of patients was based on estimated job strain, and cutoff scores to separate the 20% of subjects with the highest strain (HS group) were >28 for high demand and <36 for low-decision latitude. These values were similar to that reported by P.L. Schnall et al\textsuperscript{6} (>31 and <38, respectively). Similarly, the 20% of subjects with the highest stress test SBP reactivity was considered the HR group. As consistently reported,\textsuperscript{21,22} we could not find any worksite BP difference between complementary groups separated by their job strain or stress response. Ambulatory BP, which provides frequent assessments of BP during a wide range of daily situations, appears to be a better predictor of cardiovascular morbidity than clinic BP.\textsuperscript{23} The majority of job-related strain studies that recorded
ambulatory BP, found a higher SBP and/or DBP at work in men; the results were less conclusive in women.\(^{15,24,25}\) Nonetheless, all published studies used a case-control design that may enhance contrasts; cases involved either hypertensives or subjects with stressful occupational activities (for example, firefighter or school teacher). Case-control studies that have an underlined potential relationship between job strain and BP level may generate methodological bias. Thus, to minimize potential bias, our study was conducted in a normotensive population to quantify the association between job strain and BP. Job strain was associated with a significantly higher DBP of 4.5 mm Hg and with a nonsignificant higher SBP of 2 mm Hg. Furthermore, in our study, a higher DBP occurred only during working hours; this is contrary to the case-control studies that found a sustained effect of job strain during the entire 24 hours.\(^{16}\) However, in case-control studies, the prolonged effects of job strain are difficult to interpret because cases who are hypertensives have per se higher 24-hour BP than their normotensive controls. Because we could not find any remaining effect of job strain, a study that takes into account not only job strain but also daily life stress would be of major interest.

Because of the complexity of personal management of stress that originates from stress perception to the final physiological response, we coupled the assessment of the individual perception of job strain to the determination of individual cardiovascular reactivity to a stress test. The use of a computerized task ensured standardization of the test procedure and may account for the satisfactory reproducibility of our methodology.\(^{7}\) Such an approach used by Steptoe et al\(^{26}\) revealed that job strain was associated with an enhanced BP response to uncontrollable but not to controllable tasks. However, the BP reactivity to the controllable self-paced task was not sufficient (<4 mm Hg for SBP/DBP) to reliably discriminate subjects. Our version of the CWT, which was realized under time and experimenter pressure with an audio stimulus if the response was not accurate, can be considered as an uncontrollable task. The CWT that elicited a sustained and major increase in BP (22±1/10±1 mm Hg for SBP/DBP) could not distinguish subjects for their job strain levels. Thus, our findings do not support a relationship between uncontrollable tasks and job strain. Interestingly, individual reactivity to the laboratory stress test was not involved in the job strain–related increase in BP. This is in contrast to the findings of Matthews et al\(^{27}\) who reported that ambulatory BP (low sampling every 30 minutes) in the subgroup of vulnerable subjects submitted to a variable stress was in part explicated by the perception of strain and by the amplitude of BP reactivity to laboratory stressing. Furthermore, a high BP variability (assessed either by standard deviation or spectral power) at rest and during stress is not related to the job strain effect on BP. Our study confirms that laboratory stress tests, which are of interest to assess physiological responses to the defense reaction, do not reliably reflect daily life stress.\(^{28}\) The higher prevalence of microalbuminuria in the HR group could be related to a slight microvascular impairment\(^{29}\) caused by a higher BP surge during daily life events. This higher BP reactivity is not related to spontaneous BP variability assessed during a short period of BP recording. However, because the prevalence of microalbuminuria in normotensives is low, our results should be interpreted with caution.

The main BP-related factors (alcohol consumption, BMI, sodium intake, age, gender, and occupation), which were equally distributed between complementary groups, did not influence our conclusions. Conversely, because stress is known to favor alcohol intake, it was reported as a potential major link between stress and BP in case-control studies.\(^{21}\) However in France, the people do not drink alcohol to relieve anxiety; thus, it is not related to the job strain level. Case (hypertensives)-control (normotensives) studies could have emphasized the confounding effect of alcohol consumption because chronic alcohol intake is linked to a higher BP.

In conclusion, ambulatory BP monitoring that evaluates working BP is of major interest in analyzing job strain effects on BP. Job strain effects on DBP quantified at 4.5 mm Hg is independent from BP spontaneous variability, BP reactivity

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**TABLE 2. SBP and Heart Rate Variabilities Expressed Both as Standard Deviation (mm Hg or bpm) and as Spectral Powers (mm Hg\(^2\) or bpm\(^2\)) at Rest and During Stress**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High Strain</th>
<th>Non–High Strain</th>
<th>High Responders</th>
<th>Low Responders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest SD-SBP</td>
<td>7.3±0.3</td>
<td>7.2±0.2</td>
<td>8.1±0.3</td>
<td>6.9±0.1</td>
</tr>
<tr>
<td>Rest PLF-SBP</td>
<td>3.0±0.3</td>
<td>3.1±0.2</td>
<td>3.3±0.2</td>
<td>3.0±0.2</td>
</tr>
<tr>
<td>Rest PHF-SBP</td>
<td>1.1±0.1</td>
<td>1.1±0.1</td>
<td>1.1±0.1</td>
<td>1.1±0.1</td>
</tr>
<tr>
<td>Rest SD-HR</td>
<td>5.2±0.3</td>
<td>4.9±0.1</td>
<td>4.8±0.2</td>
<td>4.9±0.1</td>
</tr>
<tr>
<td>Rest PLF-HR</td>
<td>2.8±0.3</td>
<td>2.3±0.2</td>
<td>2.3±0.3</td>
<td>2.4±0.2</td>
</tr>
<tr>
<td>Rest PHF-HR</td>
<td>1.7±0.2</td>
<td>1.3±0.1</td>
<td>1.3±0.2</td>
<td>1.3±0.1</td>
</tr>
<tr>
<td>Stress SD-SBP</td>
<td>7.9±0.3</td>
<td>7.0±0.2</td>
<td>7.9±0.3</td>
<td>6.9±0.2</td>
</tr>
<tr>
<td>Stress PLF-SBP</td>
<td>2.9±0.3</td>
<td>3.2±0.2</td>
<td>3.7±0.3</td>
<td>2.9±0.2</td>
</tr>
<tr>
<td>Stress PHF-SBP</td>
<td>0.9±0.1</td>
<td>0.8±0.1</td>
<td>0.9±0.1</td>
<td>0.8±0.1</td>
</tr>
<tr>
<td>Stress SD-HR</td>
<td>5.3±0.3</td>
<td>4.8±0.1</td>
<td>5.4±0.3</td>
<td>4.7±0.1</td>
</tr>
<tr>
<td>Stress PLF-HR</td>
<td>2.0±0.2</td>
<td>1.7±0.1</td>
<td>1.6±0.2</td>
<td>1.8±0.1</td>
</tr>
<tr>
<td>Stress PHF-HR</td>
<td>1.2±0.2</td>
<td>0.9±0.1</td>
<td>0.9±0.2</td>
<td>1.0±0.1</td>
</tr>
</tbody>
</table>

Values are given as mean±SEM. SD indicates standard deviation; HR, heart rate; PLF, power spectrum in the low-frequency band; and PHF, power spectrum in the high-frequency band.
to stress tests, and major BP-related factors, such as alcohol intake, age, BMI, and sodium intake. The present cross-sectional study suggests that individual perception of strain should be considered as a cardiovascular risk factor.

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References
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