The Relationships Among Objective and Subjective Environmental Stress Levels and Serum Uric Acid: The Moderating Effect of Perceived Control

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This study was designed to investigate the effects of objective and subjective stress levels and perceived control on serum uric acid (SUA). Respondents were 2,504 male and 1,176 female manufacturing employees. Objective job-related stress was assessed by the Ergonomic Stress Level (ESL) inventory (S. Melamed, D. Yekutieli, P. Froom, E. Kristal-Boneh, & J. Ribak, 1999). As expected, ESL was positively associated with SUA, but among male respondents only. The measure of subjective stress, environmental annoyance, was negatively related with SUA for male respondents, thus not confirming the hypothesis. Perceived control was not found to have a direct effect on SUA, after controlling for the ESL measure. For male respondents only, perceived control moderated the relationship between ESL and SUA: This relationship was negative for those reporting above-average control and positive for those reporting below-average control.

From the early 1970s, it was evident to researchers that serum uric levels change in response to socially and psychologically stressful situations and achievement-related behaviors (Mueller & French, 1974; Mueller, Kasl, Brooks, & Cobb, 1970). However, with few exceptions (e.g., Najem, Seebode, Samady, Feuerman, & Friedman, 1997; Zorbas, Yaroshenko, & Federenko, 1996), this pattern of associations has remained relatively unexplored by behavioral science researchers. This is all the more striking in view of the epidemiological evidence implicating elevated levels of serum uric acid in the pathogenic processes leading to coronary atherosclerosis (e.g., Lee, Sparrow, Vokonas, Landsberg, & Weiss, 1995) and coronary heart disease (e.g., Brand, McGee, & Kannel, 1985; Cappuccio, Strazzullo, Farinaro, & Trevisan, 1993; Frohlich, 1993). There are exceptions to the above pattern of results, including studies in which uric acid did not predict coronary artery morbidity or mortality (e.g., Menotti, Spagnolo, Scanga, & Dima, 1992). Elevated levels of serum uric acid carry an increased risk of gouty arthritis or renal stones (Kelly & Palella, 1987) and may be toxic to the central nervous system’s activity (Muller et al., 1970).

Muller et al. (1970) noted that the possible mechanisms that link stress with central nervous system activity and with body production of serum uric acid might include metabolic precursors of serum uric acid. Twin studies conducted in the United Kingdom and United States (Boyle et al., 1967; Jensen, Blankenhorn, Chin, Sturgeon, & Ware, 1965) have indicated that environmental factors are considerably more important than genetic factors in explaining concentrations of serum uric acid. More specifically, it has been shown that exposure to objective stress, like a critical job event or a natural disaster, can produce arousal of the pituitary adrenal system and might cause elevated levels of serum uric acid (Eden, 1982; Lee et al., 1995; Trevisan et al., 1997).

On the basis of the above evidence, it is likely that adverse work and environmental conditions that may be prevalent in a typical industry might affect serum uric acid levels. To our knowledge, this possibility has not been addressed by past research. Workers in a typical industry are likely to be simultaneously exposed to safety hazards, overcrowding, cognitive and physical demands, and environmental stressors (Melamed, Yekutieli, Froom, Kristal-Boneh, & Ribak, 1999). There is evidence to support the contention that combined exposure to these factors, expressed as the ergonomic stress level (ESL), was
associated with the stress-related outcomes, such as the outcome of occupational injuries (Melamed, Luz, Najenson, Jucha, & Green, 1989).

The research model guiding our study (see Figure 1) follows the theoretical framework to the study of stress in organizations developed by Kahn and Byosiere (1992), which posits that objective and subjective environmental stress may lead to physiological response. Specifically, we designed the present study to test the hypothesis that objective and subjective environmental stress affect serum uric acid concentrations.

We have conceptualized objective environmental stress as a summary measure of several facets of objective stress at work. These facets included active safety hazards (such as lack of protection, lack of hazard warnings, and constricted escape routes), physical effort, physical discomfort, overcrowding, climate discomfort, exposure to noise, poor lighting, and vibration. Subjective stress refers to environmental annoyance, defined as the extent to which a person is disturbed by physical stressors in the work environment, such as noise, high or low ambient temperature, vibration, dust, and noxious odors (Melamed et al., 1989; Stansfeld, Clark, Jenkins, & Tarnopolsky, 1985). Certain components of environmental annoyance, such as noise annoyance, were found to predict physiological outcomes independent of objective environmental stress (e.g., Melamed, Luz, & Green, 1992). In one of our studies, both noise annoyance and noise exposure levels were found to have an additive effect on cholesterol levels in men and women (Melamed, Froom, Kristal-Boneh, Gofer, & Ribak, 1997).

In Figure 1, these relationships were represented as moderated by perceived control, a key property of the organizational situation. Perceived control refers to the employee's ability to make decisions concerning the job (see Kushnir & Melamed, 1991), which corresponded to decision authority in Karasek's demand-control model (Karasek & Theorell, 1990).

A major methodological shortcoming in the research literature is the paucity of attempts to compare objective with subjective measures of environmental stress in the prediction of health outcomes. In many survey-based studies, environmental stress was defined exclusively by the participants' descriptions of their work (see Karasek, & Theorell, 1990). This precludes the possibility to disentangle the respective effects of objective exposure and subjective appraisal of this exposure. An intervention designed to reduce exposure to objective environmental stress might be entirely inadequate for ameliorating employees' stress assessments (see Kasl, 1984). We hypothesized that both pathways, leading respectively from the objective environmental and subjective stress to the physiological strain, do coexist. To illustrate, a number of studies focusing on objective work conditions.

**Figure 1.** The research model. ESL = ergonomic stress level.
have demonstrated high physiological stress reactions, as well as a high prevalence of ill-health symptoms (cf. Karasek & Theorell, 1990; Melamed, Ben-Avi, Luz, & Green, 1995). The objective work conditions included assembly-line work, piecework, and monitoring (e.g., French, Caplan, & van Harrison, 1982; Johansson, Aronsson, & Lindstrom, 1978; Lundberg, Granqvist, Hansson, Magnusson, & Wallin, 1989). Employees’ appraisals of their work conditions appear to mediate these stress outcomes (e.g., Cox, 1985; Lundberg et al., 1989; Shirom, Westman, & Melamed, 1999). The present study was designed to address the above methodological issues by collecting data from a large sample of male and female blue-collar workers on objective work conditions, subjective stress appraisals of the same work conditions, and an objective stress outcome measure, serum uric acid.

Objective Stress and Serum Uric Acid

Kahn and Byosiere’s (1992) theoretical framework posits that physical stress in organizations, including noise, light, and vibration, may have direct impact on physiological strain. It follows that ESL could directly impact serum uric acid. Most past research of the stress–serum uric acid association in real work situations (excluding laboratory research or non-working participants) was conducted on event-based stresses like being exposed to a critical job event (Eden, 1982). A study that reported a change in serum uric acid in response to an objective stress was Kasl, Cobb, and Brooks’s (1968) investigation of employees who underwent job loss as a result of permanent plan shutdown. They found high levels of serum uric acid on the first measurement, during anticipation of the closing down of the company for which the employees had worked an average of 18 years. Serum uric acid dropped sharply back to normal among those employees who were quickly reemployed but remained high for the rest, returning to normal only when they were on a new job. The employees’ subjective reports of the severity and duration of the job loss experience were related to the amount of change in uric acid level. However, chronic stress, either objective or subjective, was not measured in this study.

In a series of studies on underwater demolition training, Rahe and colleagues (Rahe & Arthur, 1967, 1968; Rahe, Rubin, & Gunderson, 1972) found that serum uric acid concentrations rise significantly when the trainees anticipated arduous training activity that they encountered as a challenge, that is, with optimism and expectations of success. The levels of serum uric acid declined significantly when the trainees experienced overload and were unsure of successfully completing the mission. These findings are in accord with an earlier study of Brooks and Mueller (1966), who reported that among university professors, worries and feelings of being overburdened were negatively associated whereas achievement orientation was positively associated with serum uric acid. The series of studies of Rahe and his colleagues were summarized in Rahe, Rubin, and Arthur (1974) as indicating that serum uric acid levels rise above baseline when people expect a challenging physical or psychological stress. However, in this series of studies, the researchers did not measure self-reported stress or success expectations, rather they inferred these relationships from their observations of the trainees. Therefore, the steep rise and decline of serum uric acid could be associated with the different types of objective stress faced by the trainees during the different phases of the 4-month-long training period.

There are very few studies of chronic stress–uric acid relationships. Trevisan and his colleagues (Trevisan et al., 1997) studied the physiological consequences of long-term exposure to a natural disaster among employees. They reported that short-term (about 2 weeks) exposure to a major earthquake was associated with a decrease in uric acid levels. They interpreted this finding as due to overwhelming loss of control in the immediate aftermath of the disaster. Trevisan et al. also reported that long-term exposure (about 5 years) to the natural disaster was associated with an increase in the levels of uric acid. Following this line of evidence, we hypothesized (Hypothesis 1) that objective stress would be positively associated with serum uric acid levels.

Subjective Stress and Serum Uric Acid

Baron (1994) suggested that a person’s perception of physical stress in the work environment might be both an independent predictor of psychological and physiological strain and a mediator of the effects of physical stress on these strains. Employees’ perception of physical stress at work could be regarded as an indicator of their sensitivity to this environmental stress. In this study, we referred to the perceived environmental stress as environmental annoyance (cf. Melamed et al., 1989; Stanfeld et al., 1985). A possible pathway leading from subjective stress (in this study, environmental annoyance) to serum uric
acids is through the impact of the former on the sympathetic nervous system. Perceived stress may lead to the activation of the sympathetic nervous system, whose arousal may be associated with an increase in the production of serum uric acid (Ferris & Gordon, 1968). We are not aware of past research that linked chronic perceived stress with serum uric acid. However, several empirical studies provide indirect support to this line of reasoning.

House, McMichael, Wells, Kaplan, and Landerman (1979) found that the perceived occupational stress of factory workers exacerbated the deleterious effect of exposure to physical stress on these workers' health. Conrad (1973) reported that physiological strain reaction was elevated among people who were annoyed by environmental noise irrespective of the level of their exposure to it. Melamed et al. (1989) found that factory workers' reported subjective annoyance predicted risk of involvement in accidents. Noise annoyance, which tends to be positively correlated with environmental annoyance (Stansfeld, 1992), was found to be related to serum lipid levels (Melamed et al., 1997) and blood pressure (Lercher, Hortnagal, & Koller, 1993). Therefore, we formulated the second hypothesis (Hypothesis 2) thus to expect a positive relationship between environmental annoyance and levels of serum uric acid, even after controlling for the effects of objective stress.

The Effects of Control on Serum Uric Acid

The stress literature has identified a number of situational features that moderate the impact of stress on strain, in addition to their direct effects on psychological and physiological strain. Perceived control has often been investigated as a situational characteristic with considerable impact on strain and as a moderator of the effects of stress on strain. In part, this is due to the influence of Karasek's job demands-control model (Karasek, 1979). The demand-control model posits that stress and control interact in predicting strain and ill health. According to this model, a combination of high demands and low control produces the most adverse physiological and psychological outcomes (Baker, 1985). Karasek and Theorell (1990) presented data supporting the contention that the lower the control over the work process, the more pronounced the effects of physical and psychological stress on strain, including risk factors for cardiovascular heart disease (e.g., Alfredsson, Karasek, & Theorell, 1982; Karasek, Baker, Marxer, Ahlbom, & Theorell, 1981). Frese (1989) argued that both additive and interactive effects of perceived control on health should be investigated, suggesting two major mechanisms for these two types of effects. Because control implies that one can change environmental condition, certain physical stresses can be reduced or even abolished, leading in turn to a reduction of physiological strain and ill health. This mechanism has been referred to as the main effect model of control, which is viewed as directly associated with increased well-being (Barling & Kelloway, 1996). Support for the main effect of control was found in many studies (Spector, 1986).

Control may also interact with physical stress in predicting physiological outcomes. This interaction may occur because job control enables employees to modify the stressful environment, thus making it more suitable to their psychophysical prerequisites (Frese, 1989). This mechanism has been referred to as the interactive effect model of control, and it implies that the person can develop effective coping strategies with physical stress that buffer its effects on physiological stress. Evidence for the interactive model's robustness with regard to physiological outcomes has been mixed (Fletcher & Jones, 1993; Spector, 1986, 1987). We were not able to find any study involving perceived control and serum uric acid. However, following the above theoretical models and past research, we expected control to have a direct negative effect on serum uric acid (Hypothesis 3), thus representing the main effect model. In addition, we expected perceived control, in accordance with the interactive effect model, to reduce the deleterious impact of objective and subjective stress on serum uric acid (Hypotheses 4 and 5).

Certain physiological variables, including age and body weight (Lee et al., 1995; Mueller et al., 1970) and sport activity (Yano, Rohads, & Kagan, 1977), are known to be associated with higher levels of serum uric acid and therefore were used as control variables in this study. We also controlled for diabetes and certain types of medications known to have an impact on the levels of serum uric acid (Nakanishi, Suzuki, Kawashimo, Nakamura, & Tatara, 1999). The literature on uric acid depicts consistent male-female differences in concentrations of serum uric acid across the life span (e.g., Mikkelsen, Dodge, & Valkenberg, 1965; Nakanishi et al., 1999). Therefore, the hypotheses were tested separately for male and female workers. A similar decision was taken by other investigators of stress-uric acid relationships (Thomas, Goodwin, & Goodwin, 1985).
Method

Sample

The design of the present investigation is a cross-sectional study of a fairly large sample of employees in manufacturing industry. Participants were 3,680 blue-collar workers (2,504 men and 1,176 women) in the CORDIS (Cardiovascular Occupational Risk Factors Determination in Israel) study. This is a multidisciplinary, cross-sectional, and longitudinal epidemiological project aimed at identifying occupational risk factors for cardiovascular disease. The screening was offered free of charge on company time and was accepted by roughly 60% of the employees. The data collected for each participant covered a multitude of medical, biochemical, ergonomic, environmental, and psychological variables. The present study was based on data collected during Phase I of the project (1985–1987) in 21 manufacturing plants. A detailed description of the types of plants sampled, the definition of blue-collar work, the respondents who were excluded from the final sample, and the characteristics of those excluded was presented elsewhere (Melamed et al., 1995). In addition to those employees who did not complete the questionnaires (mainly because of language difficulties or because they were absent at the time of administration), we excluded from the sample those who self-reported gout as a chronic illness. Gout is a rheumatic disease, definitively diagnosed by observing crystals of sodium monourate in synovial fluid or in the tissues, often marked by abnormally high amount of serum uric acid, whose prevalence rises with age (Sturrock, 2000). Although idiopathic hyperuricaemia occurs more often than clinical gout (Sturrock, 2000), we excluded those with gout to avoid reverse causation and the confounding effects of antigout medications these respondents took.

Procedure

All test procedures, including medical examinations, blood tests, assessments of the ergonomic stress levels by experienced judges, interviews, and questionnaires, were conducted at the work site. The psychological questionnaires were presented as part of the overall medical data-gathering process and were administered individually. Two experienced observers performed the work environment evaluation, using the ESL inventory (described below) to assess the 640 workstations of the 21 plants in which the study participants were employed. The work environment evaluation was conducted independently of the psychological questionnaire and the cardiovascular disease risk factors screening, by visiting each plant several times, checking observations and measurements, and verifying their stability over the period of the study.

Measures

Concentrations of serum uric acid are considered elevated in an absolute sense when they exceed the upper limit of an arbitrary normal range (indicating solubility of monosodium urate in serum), which in most studies is 7.0 and 6.0 mg/dL for men and women, respectively (Kelly & Palella, 1987). In this study, the concentration of uric acid in the serum was assessed by a modification of the phosphotungstic acid method (Sigma, New York City, NY). Blood tests were performed on venous blood samples drawn in vacuum tubes without additives between 7 and 9 a.m. in the morning, with the participants seated and after fasting of 9–11 hr. Serum was separated from the whole blood within 2 hr of being drawn. Blood tests were carried out on fresh serum with an Abbott VP autoanalyzer (Abbott Park, IL). Internal and external quality control were used throughout. The data analysis was carried out separately for male and female respondents. Serum uric acid increases in men more than in women, perhaps influenced by the levels of estrogens and androgens; values in women are known to be constant from about age 20 through 40 but rise steeply after menopause (Kelly & Palella, 1987). These well-known differences among men and women led us to run separate regression analyses on male and female respondents.

For all multi-item indexes, described in this section, a respondent's score represented the mean of his or her responses to the items in that index. The perceived control measure was based on Quinn and Stains (1979) and consisted of six items, each scored on a 6-point scale ranging from 1 (very little) to 6 (very much). Sample items included the following: (a) To what extent are you free to determine the pace of your work? (b) To what extent are you able to initiate various things in your job? and (c) To what extent are you free to determine how to perform your work? Cronbach's alpha for this index was .82. This measure was found to be associated with both psychological distress symptoms (Kushnir & Melamed, 1991) and ambulatory blood pressure levels at work (Melamed, Kristal-Boneh, Harari, Froom, & Ribak, 1998).

Environmental annoyance was measured by a five-item index. Respondents indicated on a 5-point scale, ranging from 5 (very disturbed) to 1 (not disturbed at all), the extent to which they were bothered by noise, heat, humidity, and unpleasant odors. Cronbach's alpha for this index was .79. A detailed description of the construction of the ESL inventory and construct validation of the ESL measure is available elsewhere (Melamed et al., 1999). The ESL measure was assessed on a 4-point scale, ranging from 1 (very adequate environmental conditions) to 4 (very inadequate environmental conditions). It comprised 62 items that covered a multitude of adverse work and environmental conditions. The major clusters of these adverse environmental conditions were active hazards, falling hazards, passive hazards, poor control and safety guards, lack of protection, lack of hazard warning, physical effort, physical discomfort, overcrowding, need for sustained attention, noise disturbance, climate discomfort, lighting problems, exposure to dust, exposure to fumes, and vibration (Melamed et al., 1999). Items were transformed into normal scores to overcome the uneven distribution of item rankings across the workstations. The internal consistency reliability of the entire inventory was .95, and the value of the interobserver agreement coefficient was .97. The convergent validity of the observers' rating and those obtained by asking employees and their supervisors to evaluate the same workstations was evaluated in pilot studies. For additional details on the above convergent validity and on the consistency of the ratings across time, see Melamed et al. (1999).

The demographic variables of age, gender, and sport activity (coded as a dichotomy, with 1 = engaged in regular sport activity and 0 = not engaged in regular sport activity)
were collected in the questionnaire. Body mass index was calculated using the formula: body mass index = weight in kg/(height in m)^2. This index is also referred to as the Quetelet's index. Illness, another control variable used in this study, was scored as 1 for male employees who reported having diabetes or taking any of the following medications, including oral antidiabetics, insulin use, antihypertensive drugs, diuretics, and medication for angina pectoris, or it was scored as 0 otherwise. For female employees, the same dichotomous variable was scored as 1 for one or more of the above, plus oral contraceptive use.

Analytic Methods

In the multivariate analysis, we controlled for the confounding variables of age and body mass index, representing obesity, in a manner similar to that of French et al. (1982, pp. 26–27). Hypotheses 4 and 5 were tested by moderated multiple regressions (Aiken & West, 1991, pp. 9–10). A recent review by Aguinis, Petersen, and Pierce (1999) has revealed that moderated multiple regression is the method of choice for estimating moderating effects in applied psychology. In the regression runs, we first entered the control variables, followed by the main effects of ESL and environmental annoyance, and then perceived control. In the fourth step, we entered the multiplicative terms that were hypothesized. To reduce the possibility of multicollinearity among the product terms of the interactions and their component predictors, we centered the predictors (Aiken & West, 1992, pp. 28–35; Jaccard, Turrisi, & Wan, 1990).

Results

Table 1 represents, for each variable used in the analyses, the means for female and male respondents. As expected from previous reports in the literature (e.g., Mikkelsen et al., 1965), the concentration of serum uric acid was significantly higher among the men compared with the women in the study. With the exception of environmental annoyance, the means of all other predictors were found to be significantly higher for male compared with female respondents, in accordance with previous findings reported by Melamed et al. (1995). This finding lends credence to the contention of Martocchio and O'Leary (1989), who reported in their meta-analysis that there is no evidence for sex differences in the stress experienced by employees but argued that sex differences might emerge if stress could be measured more objectively.

Table 2 represents the matrix of intercorrelations among the study's variables. Objective (ESL) and subjective (environmental annoyance) stress were significantly correlated among male (r = .16, p < .05) but not female employees. The measure of objective stress was negatively correlated with perceived control for both male and female employees (r = -.15, p < .05). Among the control variables, sport activity was not correlated with serum uric acid for either female or male respondents and also was not a significant predictor in the regression runs. Therefore, this control variable was omitted from Table 3.

Table 3 represents the results of the two regression runs of serum uric acid on the predictors for female and male respondents. The squared multiple correlation coefficients (adjusted for degrees of freedom)
Table 2
Correlations for the Study Variables for Female (Above Diagonal) and Male (Below Diagonal) Employees

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td></td>
<td>--</td>
<td>-.08*</td>
<td>.44*</td>
<td>-.01</td>
<td>.03</td>
<td>-.08*</td>
<td>.19*</td>
</tr>
<tr>
<td>2. Sport activity</td>
<td>-.16*</td>
<td>--</td>
<td>-.12*</td>
<td>-.17*</td>
<td>.04</td>
<td>.11*</td>
<td>.01</td>
<td>-.02</td>
</tr>
<tr>
<td>3. Body mass index</td>
<td>.28*</td>
<td>-.06*</td>
<td>--</td>
<td>.03</td>
<td>-.00</td>
<td>-.10*</td>
<td>.15*</td>
<td>.30*</td>
</tr>
<tr>
<td>4. Ergonomic stress level</td>
<td>.04*</td>
<td>-.05*</td>
<td>.06*</td>
<td>--</td>
<td>.05</td>
<td>-.15*</td>
<td>-.01</td>
<td>-.04</td>
</tr>
<tr>
<td>5. Environmental annoyance</td>
<td>.05*</td>
<td>-.03</td>
<td>.03</td>
<td>.16*</td>
<td>--</td>
<td>.04</td>
<td>.04</td>
<td>.04</td>
</tr>
<tr>
<td>6. Perceived control</td>
<td>-.00</td>
<td>.10*</td>
<td>.02</td>
<td>-.05</td>
<td>-.05</td>
<td>--</td>
<td>.01</td>
<td>-.06*</td>
</tr>
<tr>
<td>7. Illness*</td>
<td>.35*</td>
<td>-.06*</td>
<td>.17*</td>
<td>-.02</td>
<td>.06*</td>
<td>-.01</td>
<td>--</td>
<td>.12*</td>
</tr>
<tr>
<td>8. Uric acid</td>
<td>.04*</td>
<td>-.01</td>
<td>.28*</td>
<td>.03</td>
<td>-.04</td>
<td>.02</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

Note. *p < .05.

Table 3
Summary of Hierarchical Multiple Regressions of Serum Uric Acid on Control Variables, Objective and Subjective Environmental Stress, and Perceived Control for Female and Male Employees

<table>
<thead>
<tr>
<th>Variable</th>
<th>Female employees (n = 1,172)</th>
<th>Male employees (n = 2,493)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SEb</td>
</tr>
<tr>
<td>Step 1: Control variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>.01*</td>
<td>.00</td>
</tr>
<tr>
<td>Body mass index</td>
<td>.05*</td>
<td>.01</td>
</tr>
<tr>
<td>Illness*</td>
<td>.17*</td>
<td>.08</td>
</tr>
<tr>
<td>Step 2: Main effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ergonomic stress level (ESL)</td>
<td>-.18</td>
<td>.10</td>
</tr>
<tr>
<td>Environmental annoyance</td>
<td>-.05</td>
<td>.03</td>
</tr>
<tr>
<td>Perceived control</td>
<td>-.03</td>
<td>.02</td>
</tr>
<tr>
<td>Step 3: Moderating effects of control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESL × Perceived Control</td>
<td>-.11*</td>
<td>.04</td>
</tr>
</tbody>
</table>

Note. The symbols B and β represent the unstandardized and standardized partial regression coefficients, respectively, and SEb stands for the standard error of the former. The symbol ΔR² stands for the incremental squared multiple correlation coefficient, adjusted for degrees of freedom, for the respective step of the regression. Only statistically significant interactive terms are presented.

*a See Table 1 for explanation of illness.

*p < .05.
Discussion

Several results seem to stand out in the regression runs, after we controlled for the effects of age, taking certain medications, and obesity. First, for male employees but not for female employees, the objective stress measure of ESL was positively correlated with serum uric acid. This finding provides some support for Hypothesis 1. Second, in contrast with our hypothesis, perceived control did not predict serum uric acid for either male or female employees. It is clear that the disordinal interaction that described the mediating effects of perceived control on ESL-uric acid relations for male employees explains the lack of support for the hypothesized main effect of control in this case. Third, after the effects of the measure of objective stress were controlled for, the measure of subjective stress (environmental annoyance) was not a significant predictor of the criterion for female employees and was a negative predictor of the criterion among male employees, again not confirming Hypothesis 2. Lastly, perceived control moderated the effects of ESL on the criterion for male employees, providing some support to the hypothesis that expected a moderating effect of control on stress-uric acid linkages.

There may be several reasons for the lack of support to our hypotheses that concerned the direct effects of ESL and environmental annoyance on serum uric acid among female employees. Female employees in our sample were less likely to be employed in workstations that were physically demanding and that had heavy workloads. Therefore, for female employees, ESL may have been less salient and probably tapped to a lesser extent potential threats as compared with male employees. Still, for female employees the hypothesis that expected environmental annoyance to predict serum uric acid was not confirmed. A possible explanation may concern the specific effects of objective versus subjective stress on serum uric acid for men as compared with women. Eden (1982), in a multiple interrupted time series study, found that the 39 first-year nursing students, all women, in his sample responded physiologically to the objective transient stress events that he had investigated, in terms of rising and then falling serum uric acid levels in four out of five measurement spells. However, these nursing students responded to the critical job event studied without reporting higher levels of subjective stress. In Eden's study, the objective stress measure used was highly relevant and salient to the female respondents. This may account for the fact that in the present study, we failed to replicate the finding that concerned objective stress effects in Eden's study. Indirect evidence supporting this interpretation comes from the study of Thomas et al. (1985), who found that in a sample of 256 healthy
elderly persons above the age of 61, social support was not correlated with serum uric acid for men in their sample, whereas it was correlated \(-0.20\) with uric acid for women in their sample. Thomas et al. argued that this may be due to the greater sensitivity of women to relationships with significant others. Other researchers (e.g., Caplan & Jones, 1975) similarly found changes in physiological strain without the predicted antecedent changes in subjective stress.

How could the negative relationship between environmental annoyance and serum uric acid among male respondents, found in this study, be accounted for? A possible explanation is that for male employees, noise, heat, humidity, and unpleasant odors—the types of physical stress tapped by this subjective measure—were perceived as externally determined and therefore led to a pattern of response of passive coping. Several past studies (Melamed, Kushnir, & Shirom, 1992; Rahe & Arthur, 1967; Trevisan et al., 1997) have reported that, under similar conditions, significantly lower levels of uric acid were found.

One of the limitations of the present study relates to the validity of the measure of environmental annoyance. This measure of subjective stress was not a commensurate reflection of the ESL measures used here. This is due to the fact that environmental annoyance did not tap employees’ perceptions of most of the items included in the objective measure of ESL. To illustrate, environmental annoyance did not cover employees’ perceptions of objective stresses such as safety hazards, overcrowding, and physical demands at work. Future research should attempt to construct more comprehensive subjective stress measures corresponding to the breadth of work-related hazards captured by the ESL measure.

Yet another major limitation of the present study is the small amount of variance of serum uric acid explained by our stress and control predictors. We studied a fairly large and representative sample of manufacturing employees. Thus, conventional significance testing procedures that were used in the regression analysis may provide an impoverished view of how seriously one can take the effects of stress and control on serum uric acid reported here. There are several arguments that can be made to support the importance of the small effects we have found.

First, the moderating effect of control beliefs on environmental stress—uric acid relationship provides support to the person-environment fit approach, as reformulated by Reich, Erdal, and Zautra (1997) to represent the interactions of control beliefs and health behaviors. According to their theoretical expectation, the interaction of control beliefs and stress accounts for a significant additional variance of health criteria over and above the main effects of stress and control (Reich et al., 1997). It is clear that male employees in our sample who held strong beliefs about possessed control were less susceptible to the physical dysfunction of environmental stress as compared with those with below-average perceived control. A similar interaction of perceived control and stress was reported in another study in which the criterion was systolic ambulatory blood pressure (Melamed et al., 1998).

Future research may address the specific mechanisms underlying these effects. These mechanisms may include the possibility that those respondents with strong control beliefs adopted proactive coping strategies with respect to environmental stress, or sought more health-related information, or assumed responsibility for their health habits compared with the group of male employees with below-average perceived control (see Rodin, 1986).

Second, our results on the relations between stress and uric acid may suggest that for some categories of respondents, highly relevant stress, like proximal environmental stress, may involve raised levels of stimulation and arousal that lead subsequently to elevated levels of serum uric acid. It has been observed (Theorell et al., 1998; Theorell, Lind, Froberg, Karlsson, & Levi, 1972) that serum uric acid concentration reflect the general activation level in the sympathoadrenergic-medullary system. This possibility needs to be addressed in future research.
In sum, in most manufacturing jobs, physical stresses at work are very important for male employees. A physiological pathway through which physical stress affects health may be through serum uric acid. We offer this argument because it is possible that in the evolutionary process, uric acid acted as an endogenous cortical stimulant (Muller et al., 1970). Our research suggested that male employees who exert themselves in their jobs, such as by bending over in awkward positions, and had little control over their work processes were at greater risk for high levels of serum uric acid. Their coworkers who had high control over their work processes were relatively protected from the adverse effects of physical stress on their job on serum uric acid.

References


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