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Consistency in Catecholamine and Cortisol Excretion Patterns Over Experimental Conditions

ULF LUNDBERG AND LENNART FORSMAN

Department of Psychology, University of Stockholm and Karolinska Institutet Stockholm, Sweden

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LUNDBERG, U. AND L. FORSMAN. *Consistency in catecholamine and cortisol excretion patterns over experimental conditions.* PHARMAC. BIOCHEM. BEHAV. 12(3) 449–452, 1980.—Measures of adrenaline, noradrenaline and cortisol excretion and heart rate in five experimental conditions (three for heart rate) and three baseline conditions were obtained from 24 male and 24 female university students. For each sex group correlation coefficients between variables were calculated on the basis of (1) absolute measures, (2) absolute differences between experimental and baseline measures, and (3) experimental measures expressed as log percentages of baseline measures. For both sex groups and for the three types of data it was consistently found that adrenaline excretion correlated significantly and positively with noradrenaline, cortisol and urine excretion and that cortisol excretion correlated significantly with urine excretion. Furthermore, in females, absolute measures of noradrenaline were significantly positively correlated with heart rate.

Adrenaline Noradrenaline Catecholamines Cortisol Heart rate Response consistency Males Females Correlation

TWO neuroendocrine systems have been of specific interest in relation to coping and stress, i.e., the sympathetic-adrenal medullary and the pituitary-adrenal cortical systems. With few exceptions [6,13] the two systems have been studied one at a time, e.g., catecholamine excretion as an index of adrenal-medullary activity and cortisol excretion as an index of adrenal-cortical activity.

This paper is based on data from a series of experiments, which were all performed on the same male and female subjects. The experimental situations were designed to induce different degrees of effort. Concomitant measures of urinary catecholamine and cortisol excretion and heart rate obtained in the different conditions, made it possible to study the relation between these variables under different conditions. Originally, the subjects had been selected for the experiments on the basis of their scores on a questionnaire measuring the coronary-prone behavior pattern (A) [9]. However, the neuroendocrine response pattern was very similar for the Type A and the Type B subjects and, therefore, the present analyses were based on Type A and Type B subjects of each sex treated together. (For reports of additional data on Type A and Type B behavior, the reader is referred to [7] and [10]).

METHOD

The subjects were 24 male and 24 female university students, aged 18 to 34 yr (mean 24.5 yr). Body weight of the males ranged between 57 and 105 kg (mean 71.1, SD=11.9) and that of the females between 43 and 66 kg (mean 56.6, SD=5.8). Each subject was examined under the following experimental conditions: (1) monotonous vigilance task, (2) various undemanding tasks, e.g., time estimation, (3) self-paced reaction time (RT) task, (4) color-word conflict task, and (5) non-engaging movie. Conditions 1, 2, and 3 were arranged on one and the same day, each subject being tested individually. On a separate day the subjects attended conditions 4 and 5 in small groups. Each condition lasted about 70 min.

The subjects were carefully instructed to empty their bladder at each occasion of urine collection and urine samples were obtained after each condition. Adrenaline and noradrenaline excretion were assessed fluorimetrically [1,4] and cortisol by radioimmunoassay [5,12]. Heart rate was telemetrically recorded in conditions 1, 2, and 3 via a photo pickup attached to the subject's index finger. Mean heart rate was calculated for each subject and condition.

Since the five experimental conditions took place at different times of the day, diurnal variations in endocrine activity and heart rate were checked on another day. Baseline conditions and conditions 1, 4, and 5 are described in more detail in previous reports [7,10].

RESULTS

Neuroendocrine Responses in Experimental Conditions

The mean excretion (pmol/min/kg) of adrenaline, norad-

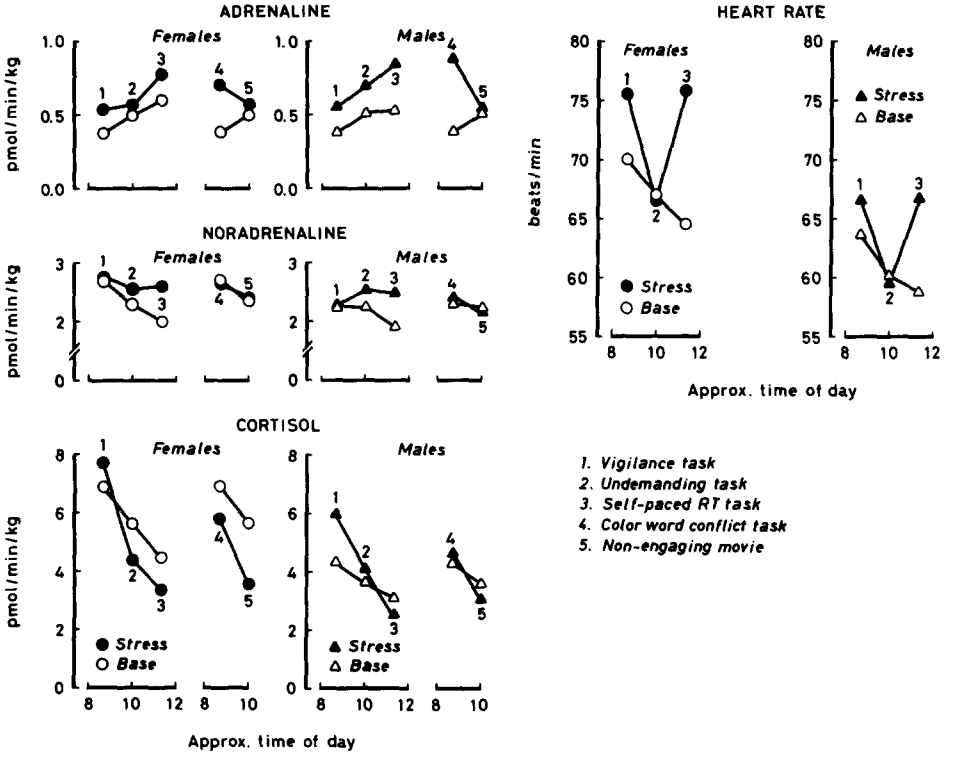

FIG. 1. Means for adrenaline, noradrenaline and cortisol excretion and heart rate for females and males in experimental and baseline conditions performed between 8:30 a.m. and 12:00 noon. (Since conditions 4 and 5 took place at the same time of day as conditions 1 and 2, the same baseline conditions are used as reference points.)

renaline, and cortisol and mean heart rate (beats/min) of females and males in each of the five (three for heart rate) experimental conditions and in the three baseline conditions are shown in Fig. 1. (As conditions 4 and 5 took place at the same time of day as conditions 1 and 2, the same baseline values are used as reference points.)

In the baseline session, catecholamine and cortisol excretion followed their normal diurnal pattern (cf. [13]). In the five experimental conditions the three neuroendocrine variables responded differently. Adrenaline excretion increased significantly ($p<0.01$ or $p<0.001$) in all conditions except condition 5 (nonengaging movie); noradrenaline excretion increased significantly ($p<0.001$) only in condition 3 (self-paced RT task); cortisol excretion increased significantly ($p<0.01$) in condition 1 (vigilance task) and decreased significantly ($p<0.05$) in conditions 3 and 5; heart rate was significantly elevated ($p<0.001$) in conditions 1 and 3. Urine excretion was not significantly affected in any of the five experimental conditions.

Correlations Between Catecholamine and Cortisol Excretion and Heart Rate

Three types of scores were calculated for each subject: (1) absolute measures in terms of pmol/min for adrenaline, noradrenaline and cortisol excretion and in terms of beats/min for heart rate, (2) absolute differences between experimental and baseline measures, taken at the same hour of the day, and (3) experimental measures expressed as log percentages of corresponding baseline measures. The reason for using two types of difference scores was that it is not clear how neuroendocrine responsiveness during stress is related to baseline measures. Measures of body weight and diuresis (ml/min) were also included in the analyses.

For each of the three types of scores, product moment correlations were calculated between variables. For each sex group, eight correlation matrices (six for heart rate) were obtained for each sex on the basis of the absolute measures, and five (three for heart rate) for each of the two types of change scores. For each of the three types of scores, the correlation matrices were found to be very similar in the different conditions, i.e., the same variables were found to be significantly intercorrelated. Therefore, each correlation coefficient was transformed into Ficher's Z and a mean correlation matrix was calculated for each type of score. The correlation matrices obtained for the absolute scores for the two sex groups are shown in Table 1. As it was found that the absolute difference scores and the log percent change scores produced the same correlational pattern, only the correlations for the absolute difference scores are presented in Table 2. The significance levels indicated in Tables 1–2 are based on the number of degrees of freedom produced via the Z-transformation.

The two correlation matrices consistently show that adrenaline excretion was significantly positively correlated with noradrenaline, cortisol, and urine excretion, and that cortisol was significantly correlated with urine excretion, too. In addition, Table 1 shows that in females, the absolute level of noradrenaline excretion was significantly positively correlated with heart rate.

TABLE 1

PRODUCT-MOMENT CORRELATION COEFFICIENTS CALCULATED OVER SUBJECTS ON THE BASIS OF ABSOLUTE MEASURES OF ADRENALINE (pmol/min), NORADRENALINE (pmol/min), CORTISOL (pmol/min), AND URINE EXCRETION (ml/min), HEART RATE (beats/min) AND BODY WEIGHT (kg). EACH VALUE REPRESENTS THE MEAN OF EIGHT (SIX FOR HEART RATE) CORRELATIONS

		Variable				
Variable		Adr.	Noradr.	Cortisol	Diuresis	Heart rate
Noradr.	Females	0.453†				
	Males	0.384†				
Cortisol	Females	0.286*	0.092			
	Males	0.456†	0.040			
Diuresis	Females	0.410†	0.224	0.601†		
	Males	0.407†	0.021	0.518†		
Heart rate	Females	0.106	0.400†	−0.135	−0.016	
	Males	0.108	−0.045	−0.088	0.017	
Body weight	Females	0.039	−0.016	−0.222	−0.056	−0.116
	Males	−0.059	0.200	−0.007	−0.001	0.157

*$p<0.05$; †$p<0.001$.

TABLE 2

PRODUCT-MOMENT CORRELATION COEFFICIENTS CALCULATED OVER SUBJECTS ON THE BASIS OF ABSOLUTE DIFFERENCES BETWEEN EXPERIMENTAL AND BASELINE MEASURES OF ADRENALINE (pmol/min), NORADRENALINE (pmol/min), CORTISOL (pmol/min), AND URINE EXCRETION (ml/min), AND HEART RATE (beats/min). EACH VALUE REPRESENTS THE MEAN OF FIVE (THREE FOR HEART RATE) CORRELATIONS

		Variable			
Variable		Adr.	Noradr.	Cortisol	Diuresis
Noradr.	Females	0.582†			
	Males	0.380†			
Cortisol	Females	0.454*	0.210		
	Males	0.496†	0.143		
Diuresis	Females	0.540†	0.321	0.497*	
	Males	0.359	−0.038	0.338	
Heart rate	Females	0.131	0.271	0.178	−0.007
	Males	0.111	0.263	−0.022	−0.073

*$p<0.01$; †$p<0.001$.

DISCUSSION

The correlations between variables (Tables 1–2) show that subjects with, say, high adrenaline excretion tend to have high noradrenaline, cortisol, and urine excretion (Table 1), and that those who respond to an experimental stressor with, say, a large increase in adrenaline excretion tend also to respond with a large increase (or relatively low decrease) in noradrenaline, cortisol, and urine excretion (Table 2). Thus, the absolute scores, as well as the change scores, form a very consistent pattern in all conditions.

The possible role played by urine flow in these relationships is not clear. Catecholamine excretion has been found to be positively related to diuresis [8], while urine volume as such has been found not to affect catecholamine excretion rate [2]. In stress, catecholamine excretion as well as diuresis, increase, although the increase in diuresis is of a relatively small magnitude (cf. [8]). In the present study, as well as in our previous studies, it has been found that the intraindividual consistency in catecholamine excretion is very high. Thus, it is not likely that momentary changes in diuresis and in efficiency of voiding could explain the correlational pattern shown in Tables 1–2. The data rather suggests that the intraindividual consistency is high not only for the separate excretion of catecholamines and cortisol, but also that the total pattern of excretion is consistent.

It is important to notice the difference between the intraindividual consistency in excretion pattern shown in Tables 1–2 and the dissociation found between adrenaline and cortisol excretion, when the mean excretions are studied in the different experimental conditions (see Fig. 1 and ref. [11]).

There was no significant correlation between body weight and catecholamine or cortisol excretion in the present data. The relatively small variation in body weight between subjects of the same sex may have contributed to this. According to previous studies (e.g., [3]), baseline adrenaline excretion is about the same in males and females only when the excretion rate is related to body weight.

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REFERENCES

1. Andersson, B., S. Hovmöller, C.-G. Karlsson and S. Svensson. Analysis of urinary catecholamines. An improved auto-analyzer fluorescence method. *Clin. Chim. Acta.* **51:** 13–28, 1974.
2. Aslan, S., L. Nelson, M. Carruthers and M. Lader. Effect of urinary pH and flow rate on catecholamine excretion. *Br. J. clin. Pharmac.* **7:** 311–312, 1979.
3. Collins, A. and M. Frankenhaeuser. Stress responses in male and female engineering students. *J. Hum. Stress* **4:** 43–48, 1978.
4. Euler, U. S. v. and F. Lishajko. Improved technique for the fluorimetric estimation of catecholamines. *Acta physiol. scand.* **51:** 348–355, 1961.
5. Ficher, M., G. C. Curtis, V. K. Ganjam, L. Joshlin and S. Perry. Improved measurement of corticosteroids in plasma and urine by competitive protein-binding radioassay. *Clin. Chem.* **19:** 511–515, 1973.
6. Frankenhaeuser, M. Psychoneuroendocrine approaches to the study of emotion as related to stress and coping. In: *Nebraska Symposium on Motivation 1978,* edited by H. E. Howe and R. A. Dienstbier. Lincoln: University of Nebraska Press, 1979, pp. 123–161.
7. Frankenhaeuser, M., U. Lundberg and L. Forsman. Dissociation between adrenal-medullary and adrenal-cortical responses to an achievement situation characterized by high controllability: Comparison between Type A and Type B males and females. *Biol. Psychol.,* in press, 1980.
8. Levi, L. Stress and distress in response to psychosocial stimuli. *Acta med. scand.,* Suppl. **528:** 717–766, 1972.
9. Lundberg, U. Type A behavior and its relation to personality variables in Swedish male and female university students. *Scand. J. Psychol.,* in press, 1980.
10. Lundberg, U. and L. Forsman. Adrenal-medullary and adrenal-cortical responses to understimulation and overstimulation: Comparison between Type A and Type B persons. *Biol. Psychol.* in press, 1979.
11. Lundberg, U. and M. Frankenhaeuser. Pituitary-adrenal and sympathetic-adrenal correlates of distress and effort. *J. Psychosom. Res.,* in press, 1980.
12. Ruder, J. H., R. L. Guy and M. B. Lipsett. A radioimmunoassay for cortisol in plasma and urine. *J. clin. Endocr. Metab.* **35:** 219–224, 1972.
13. Ursin, H., E. Baade and S. Levine. *Psychobiology of Stress.* New York, San Francisco and London: Academic Press, 1978.
14. Åkerstedt, T. and L. Levi. Circadian rhythms in the secretion of cortisol, adrenaline and noradrenaline. *Eur. J. Clin. Invest.* **8:** 57–58, 1978.