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EFFECT OF MILD PSYCHOLOGICAL STRESS ON PHYSIOLOGICAL RESPONSES TO EXERCISE IN MEN

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To find out whether a negative shift in subject's mood alters cardio-respiratory and endocrine responses to exercise, 20 young men performed a graded bicycle ergometer test (50, 100, 150 W): 1) when they experienced a mixed emotional and cognitive stress before exercise (1st session), 2) when they were familiarized with the laboratory and rested quietly before exercise (2nd session).
The subjects' mood was assessed by the Profile of Mood State (POMS) questionnaire. In the 1st session the subjects started exercise with significantly higher scores of tension, anger, depression, confusion and global mood in comparison with the 2-nd session. They also had slightly elevated systolic blood pressure, blood lactate, plasma cortisol and noradrenaline concentrations. During exercise performed in the 1st session only plasma free and total noradrenaline and cortisol levels were higher than those in the 2nd session.
In conclusion: a mild psychological stress, causing the mood worsening before standard exercise test, does not evoke pronounced alterations in cardio-respiratory responses to exercise in healthy men, but it does affect the magnitude of exercise-induced changes in both plasma free and total noradrenaline concentrations.

Key words: *psychological stress, exercise, blood lactate, plasma cortisol, plasma catecholamines.*

INTRODUCTION

It is commonly known that psychological stress influences some physiological variables such as heart rate or blood pressure and endocrine functions (1—7).

Little is known, however, to what extent conditions where subjects may experience a mild psychological stress affect cardio-respiratory, metabolic and endocrine responses to exercise tests and the test-retest reliability. Such conditions may occur e.g. when subjects are unfamiliar with procedures, intimidated by the laboratory environment, or during the pre-employment fitness testing.

Therefore, in the present study physiological responses to graded exercise were compared in the same subjects coming to the Laboratory for the first and the second time. In addition, during the first session the subjects were submitted to a mild psychological stress. In both sessions the subjects' mood was estimated by the "right now" Profile of Mood State (POMS) questionnaire (8).

Among the physiological variables that can be modified by psychological factors the interest of many investigators has been focused on the sympathoadrenal system activity. It is known, however, that the plasma free catecholamines (CA) are rapidly (within seconds) removed from blood, so the changes in the sympathoadrenal activity may be difficult to follow basing on the plasma free CA measurements. On the other hand, a large part of free catecholamines become sulfatized in blood and the half life of the bound CA fraction in blood is 1—2 hours (9). It was decided, therefore, to determine both forms of CA in this study.

MATERIAL AND METHODS

Subjects

Twenty male University students of the mean age 22.9 (S. D) 2.2 years, body mass 75.7 (S. D) 9.8 kg, and height 181.2 (S. D) 5.3 cm. volunteered to participate in this study after giving their informed consent. None of the subjects was involved in regular physical training.

Procedure

Each subject took part in 2 experimental sessions always at the same time of the day, between 8.00 a.m. and 10.00 a.m. During both sessions the students were asked to come to the Laboratory 2h after light breakfast.

Prior to the start of experiment they had an indwelling catheter inserted into the antecubital vein, to take blood samples for lactate (LA), catecholamine (CA), and cortisol determinations. At the end of 30 min rest period in the sitting position the subjects filled the mood questionnaire. Afterwords their baseline measurements of blood pressure (BP) and heart rate (HR) were made and initial blood samples were withdrawn with 10 min interval between them. Then, in the 1st session each subject was submitted to the computer I. Q. quiz, consisting of 45 tasks, during which the accompanying psychologist made challenging remarks concerning speed and accuracy. The total duration of the test was limited to 30 min. Immediately after completing the I. Q. quiz the subjects' mood was assessed again, their BP and HR were measured and the subsequent blood sample was taken. Five min after I. Q. quiz the students started a graded bicycle ergometer (Siemens, Germany) exercise consisting of 3 work loads: 50, 100 and 150 W, each maintained for 6 min. During physical exercise oxygen uptake was measured using Ergo-Oxyscreen (Jaeger, GmbH, Wuerzburg, FRG) at the end of each exercise load, and immediately after this measurement subsequent blood samples were taken. Besides, HR and BP were recorded every 2 min, and the perceived exertion was estimated at the end of each load. The subjects' mood was assessed for the last time within 5 min after finishing the exercise test. During the 2-nd session a few days following the 1-st one the same subjects performed identical exercise immediately after the initial 30 min resting period (without psychological stress).

Methods

The HR was calculated from the electrocardiogram (ECG) and blood pressure was measured by Korotkoff method.

Psychometric assessments

The subjects' mood was estimated using the Profile of Mood State (POMS) questionaire, which assesses tension, depression, anger, vigor, fatigue and confusion (8). A global measure of mood was also computed by summing up the scores for five negative moods, subtracting the vigor score, and adding a constant of 100 in order to obtain positive values. The higher the global mood score the worse the subjects' mood.

To estimate the perceived exertion (RPE) during physical exercise the 15-graded scale of Borg (10) was used.

Analytical methods

Blood LA level was determined enzymatically using commercial kits (Boehringer Diagnostica, Mannheim, FRG). Plasma cortisol concentration was measured by the radioimmunoassay, using antibodies produced by the Institute of Animal Physiology and Nutrition Pol. Acad. Sci. (Jablonna n. Warsaw, Poland). Plasma free adrenaline (A) and noradrenaline (NA) levels were determined by the High Performance Liquid Chromatography (HPLC) with electrochemical detection (11). Besides, total catecholamines (free plus sulfoconjugated) were estimated by HPLC after enzymatic hydrolysis with arylsulfatase VI (Sigma, St. Louis M. O., U.S.A.). The assay coefficient of variation was 11.5% for noradrenaline and 12.0% for adrenaline.

Statistical analysis

A repeated measurement analysis of variance (ANOVA) followed by the Student's t-test for paired samples was used to test for differences between the 1st and the 2nd session.

RESULTS

The alterations in the subjects' mood across the experimental sessions are summarized in *Table 1*.

In the 1st session after the pre-experiment rest the subjects had significantly higher scores for tension, anger, confusion, and the global mood than those in the 2nd session. After the I. Q. quiz there was a further increase in anger, depression and confusion and a decrease in vigor score. As a result the global mood score was significantly elevated. After exercise following the psychological stress the scores of all negative moods, except fatigue, significantly decreased which in turn reduced the global mood score. In the 2nd session exercise caused no changes in the subjects' mood state, except that it increased fatigue.

Table 1. Changes in mood scores (POMS) after I. Q. (1st experimental session) and after physical exercise (both sessions). Values are means ± S.E.

POMS SCORES	Session 1 R	Session 1 pIQ	Session 1 pEx.	Session 2 R	Session 2 pEx.
TENSION	8.1 ± 1.3	9. ± 1.5	2.08*** ± 1.0	3.2^{+++} ± 0.9	3.3 ± 1.1
ANGER	10.2 ± 1.0	14.8 ± 1.7	9.1 *** ± 1.0	7.1^{++} ± 0.8	7.4 ± 0.7
DEPRESSION	8.5 ± 1.2	13.3*** ± 1.9	7.9*** ± 1.4	7.4 ± 1.3	7.5 ± 0.9
FATIGUE	6.4 ± 1.0	7.8 ± 1.0	10.1* ± 1.2	6.2 ± 1.2	11.3** ± 1.3
VIGOR	18.0 ± 1.1	16.0* ± 1.2	18.2*** ± 1.0	19.7 ± 1.1	18.8 ± 1.3
CONFUSION	5.3 ± 0.7	7.3*** ± 1.1	4.5** ± 0.9	2.8^{+} ± 0.9	3.3 ± 0.7
GLOBAL MOOD	120.4 ± 4.0	136.3* ± 6.8	116.2** ± 4.6	106.9^{+} ± 4.7	114.0 ± 3.7

Asterisks indicate significant differences in comparison with preceding values, within the same session: * — $p < 0.05$, ** — $p < 0.01$, *** — $p < 0.001$. Crosses indicate significant differences between 2 sessions: $^{+}$ — $p < 0.05$, $^{++}$ — $p < 0.01$, $^{+++}$ — $p < 0.001$. R — initial rest, pIQ = post IQ, pEx = post exercise.

During the first session students estimated the perceived exertion at 50, 100 and 150 W as 9.0 ± (SE) 0.3, 11.7 ± 0.3, and 14.9 ± 0.3 points of Borg's scale, respectively. The values obtained during the 2nd session were 8.3 ± 0.2, 11.2 ± 0.3 and 14.3 ± 0.3, respectively. The differences between the sessions were insignificant.

Exercise oxygen uptake at the load of 50 W was slightly, but significantly higher in the 1st than in the 2nd session [0.995 ± (S.E) 0.04 vs. 0.894 ± 0.04 $l \cdot min^{-1}$, $P < 0.05$]. At higher work loads the inter-session differences became insignificant.

The base line values of systolic BP were significantly higher in the subjects coming to the Laboratory for the first time than for the second time while in HR an opposite difference was noted. After the I. Q. quiz HR was elevated ($P < 0.001$) in comparison with the base-line value, so the subjects started exercise with similar HR in the 1st and the 2nd session. During the graded exercise HR reached similar levels in the 1st and 2nd session, and the systolic BP showed only a tendency towards higher values in the former ($P > 0.05$). When the exercise-induced response of BP were analyzed it appeared that increases in the systolic BP at 50, and 100 W were smaller in the 1st session than in the 2nd one. The base-line values of blood LA concentration were similar in both sessions. After I. Q. quiz there was a marked increase in this variable ($P < 0.001$), however, the values of LA reached during exercise did not differ significantly between the two sessions (*Fig. 1*).

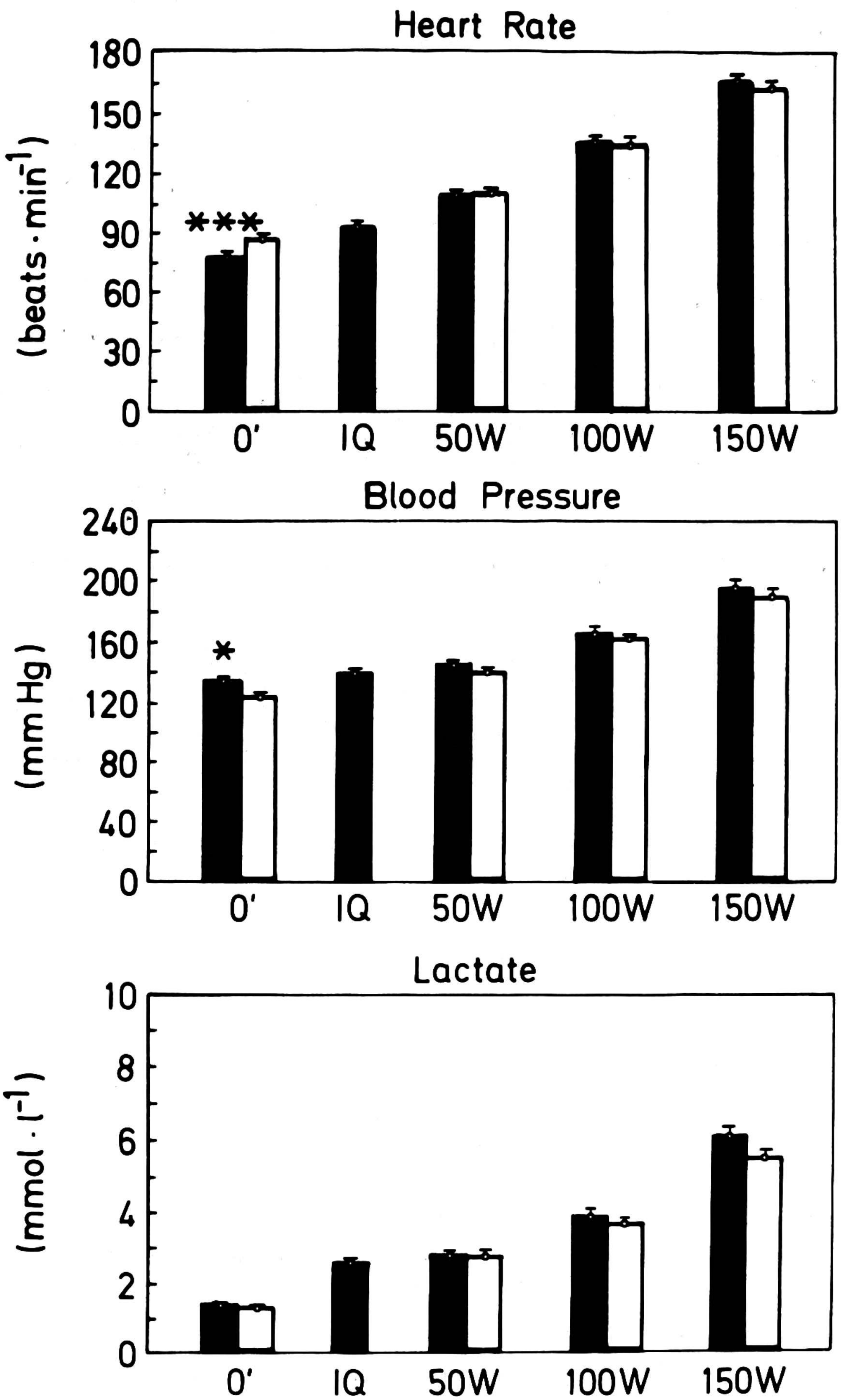

Fig. 1. Heart rate, systolic blood pressure and blood lactate concentrations (means ± SE) during the 1st (black bars) and 2nd (open bars) experimental session. O′ — initial resting period, IQ — after IQ quiz, 50, 100 and 150 W values obtained in the last minute of each exercise load. Asterisks denote significant differences between the corresponding values obtained in the two sessions. *x* — $P<0.05$, *xx* — $P<0.01$, *xxx* — $P<0.001$

The initial levels of plasma free adrenaline (A) in the two sessions, did not differ, and the I. Q. quiz had no effect on the plasma concentration of this hormone. During physical exercise in both situations the plasma free A increased significantly at 100 and 150 W ($P<0.001$), with a tendency towards higher levels in the session with psychological stress (*Fig. 2*). No changes in the total plasma A were found in either session.

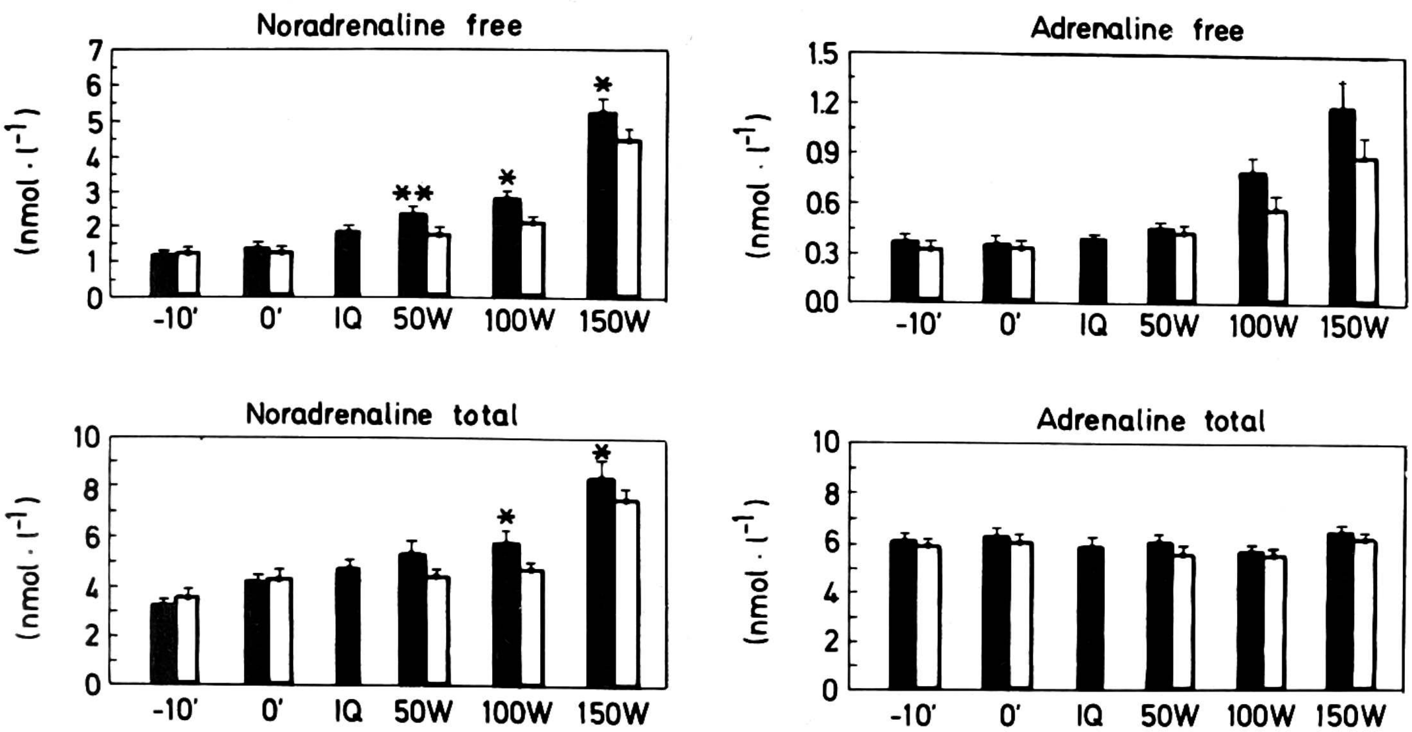

Fig. 2. Plasma free and total catecholamine (means ± SE) concentrations during the 1st (black bars) and 2nd (open bars) experimental session. Denotations as in *Fig. 1*.

The initial levels of the plasma free and total NA were nearly identical in two experimental sessions. After the I. Q. quiz similar increases in the free ($P<0.001$) and total ($P<0.05$) NA (by approx. 0.5 nmol · l^{-1}) were found. During physical exercise in both sessions a significant elevation of the plasma free NA concentration occurred already at 50 W ($P<0.01$), whereas the increase in the plasma total NA was not shown until 100 W ($P<0.01$ in the 1-st session, and $P<0.05$ in the 2nd one). Plasma free NA concentration was significantly higher in the 1-st than in the 2-nd session at all exercise loads (*Fig. 2*). Significant differences between the two sessions in the total NA concentrations were found at 100 and 150 W.

Throughout the 1st experimental session (including the base line measurements) the plasma cortisol concentrations were significantly elevated above the values obtained in the 2nd session with no effect of either I. Q. quiz or physical exercise on the level of this hormone (*Fig. 3*).

The relationships between the mood scores and the plasma catecholamine and cortisol concentrations were in most cases insignificant. However, in the first experimental session significant correlations were ascertained between the

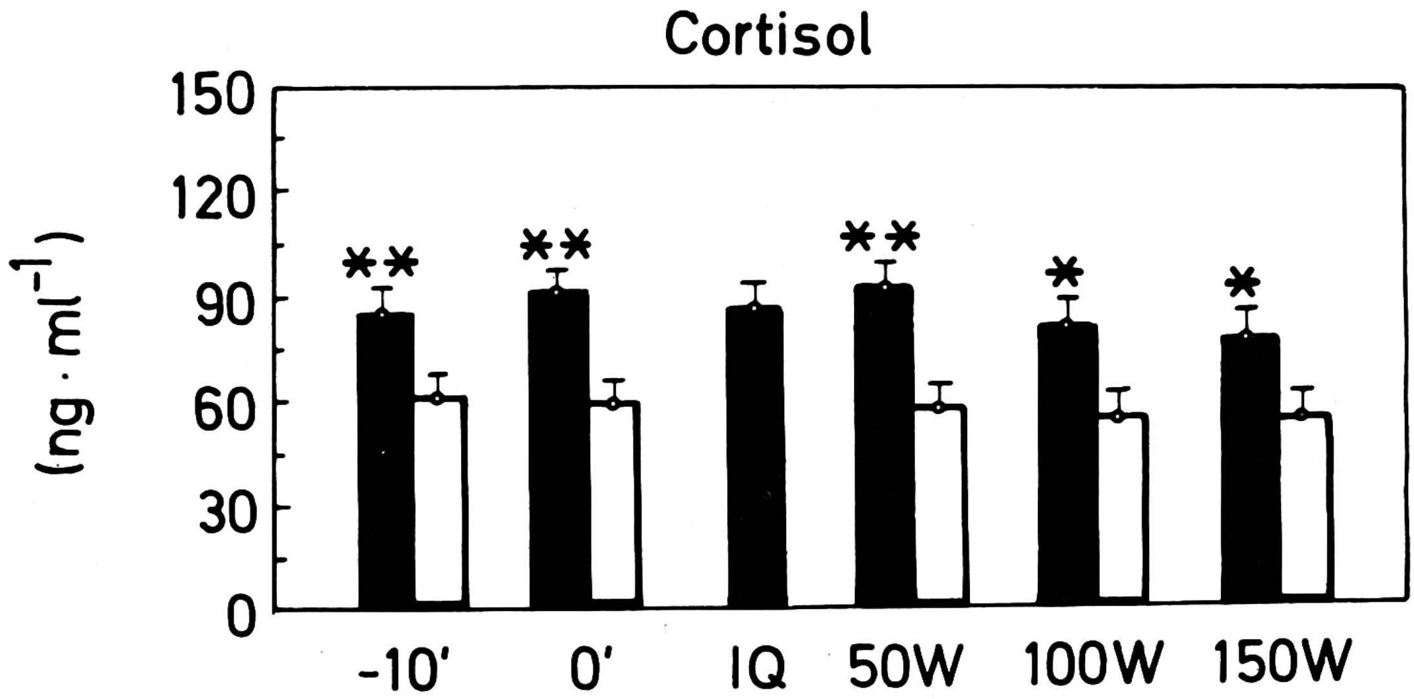

Fig. 3. Plasma cortisol concentrations (means ± SE) during the 1st (black bars) and 2nd (open bars) experimental session. Denotations as in *Fig. 1*.

global mood score and the plasma free NA levels estimated before and after I. Q., quiz [$r = 0.46$, ($n = 40$) $P < 0.001$], as well as between the tension score and the plasma cortisol level, [$r = 0.33$, $P < 0.05$], Besides, the plasma cortisol levels measured at rest (including the base line values in both sessions and the post—I. Q. quiz values in the first session) correlated significantly with the global mood score [$r = 0.29$, ($n = 60$) $P < 0.05$] and in particular with the tension score [$r = 0.42$, ($n = 60$) $P < 0.001$].

DISCUSSION

The results of the psychometric measurements showed that the mood state of subjects in the 1st session differed from that in the 2nd session already in the initial resting period. The significantly higher scores were found in tension, anger, confusion and global mood, thus indicating that novelty of the situation during the first visit to the Laboratory, and anticipation of the I. Q. test negatively shifted the mood state of the subjects. This was accompanied by a slightly increased systolic BP, and elevated plasma cortisol concentration. The level of this hormone was significantly correlated with the tension score, and to the lesser degree with the global mood score. However, it is questionable, whether a relationship that accounts for as little as 9% of the variance is truly meaningful. The differences between the two experimental sessions in the plasma cortisol concentration can be compared to those obtained by Johansson et al (4) in the students before examination and on a control day. The cited authors attributed the elevated plasma cortisol to the anxiety preceding the challenging task and not to the mental effort during examination. The mixed emotional and cognitive stress, in the form of I. Q. quiz applied in the present study, caused further increases in anger, and confusion, as well as elevations in depression scores, so the global mood score before the start of physical exercise was markedly higher in the 1st than in the 2nd session. Plasma catecholamines in the initial resting period were similar in the two sessions, whereas after the I. Q. quiz a significant increase was found in the plasma total and free NA concentrations without significant alterations in the plasma A level. The latter finding does not confirm the assumption that the emotional stress results in a predominant increase in adrenaline secretion (3, 5). However, a pronounced increase in the plasma free NA but not A was reported in students immediately after an end-of year examination (12), Moreover the significance of changes in the plasma NA level as an index of behavioral stress was emphasized by Dimsdale et al. (2). The degree of stress in various studies is difficult to compare, and to our knowledge there are no data relating the mood state or specific emotions to the pattern of changes in the plasma catecholamines during physical effort. In the present study a significant correlation was found between the global mood and the plasma free NA concentration, confirming a possibility that increased plasma noradrenaline is consequent to the mood disturbance.

It seems of interest that in all subjects examined in this work blood LA concentration increased after the I. Q. quiz, reaching the values similar to those obtained during the bicycle-ergometer exercise at the load of 50 W. In order to find out whether this increase was due to merely operating the computer *per se* or to the emotional stress during the applied I. Q. quiz blood LA concentration was measured in the members of the Department staff before, and at the end of 30 min working with the same computer, but without emotional involvement (unpublished data). In none of 8 subjects blood LA reached values comparable to those in the students after the I. Q. quiz. It seems unlikely that the elevation of blood LA in the students after the quiz is caused by a metabolic effect of catecholamines. Only in some subjects (9 out of 20) there was an increase in the plasma free A concentration after this test. Moreover, the hormone level did not reach the threshold for inducing an elevation in blood LA (13). The most probable explanation of the blood LA increment is the involuntary muscle tension accompanying the emotional stress.

A comparison of physiological responses to graded exercise in the same subjects being in different mood state did not show any pronounced differences except that after psychological stress the oxygen uptake (V_{O_2}) at the work load of 50 W was slightly (approx. by 0.100 $l \cdot min^{-1}$) but significantly higher ($P < 0.05$) in the 1st than in the 2nd session. This increase in (V_{O_2}) may be caused by an elevation of the metabolic rate under persisting psychological stress.

The perceived exertion, assessed by Borg's scale, has been proved to be closely correlated with work intensity, and heart rate achieved at a given work load. Thus, it seems mostly related to physiological changes induced by exercise (14). It has been suggested, however, that aversion to the task, as well as positive motivation, and possibly the state of arousal may also influence the rating of perceived exertion (15). The present study clearly demonstrated an increasing RPE with exercise intensity in both sessions, without any effect of changes of mood preceding exercise on the effort perception.

Mood assessment made in the 1st session immediately after the end of exercise test revealed a marked improvement of the subjects' mood with significant reduction of tension, anger, depression and confusion scores. This remains in agreement with previous reports showing an anxiolytic effect of acute exercise (16). It should be noted, however, that in the 2nd session exercise did not cause any significant changes in POMS scores, except fatigue which was increased. This finding confirms the suggestions of Youngstedt et al. (17) that the anxiety-reducing effect of exercise depends on the pre-exercise anxiety score.

In both sessions the plasma free catecholamine concentrations showed a typical relation to the exercise load (18, 19). This relation was also found in case of the plasma concentration of total NA but not of the total A, which remained virtually unchanged during the graded exercise test in both sessions. The pattern of changes in free and total adrenaline may suggest that during a short-term submaximal exercise an increase in free A is, at least partly, due to liberation of this hormone from its bound form. Such a possibility has been indicated by Weicker (20). On the other hand, an enhanced plasma free NA, accompanied by a similar increment of the total NA, suggests that the former is freshly secreted, most probably from the sympathetic nerve endings.

The most important finding of the present study is that the increase in the plasma free NA concentration, following a mild psychological stress, persists during the whole exercise period, so at each work load the levels of this catecholamine were higher in the 1st than in the 2nd session. It should be emphasized that the exercise duration was 18 min. Thus, it seems unlikely that the surplus NA, released before exercise as a result of psychological stress, could remain in blood for such a long time, adding to the normal exercise-induced NA increases. These data suggest that the preceding cognitive emotional stress could either enhance sensitivity of the sympathetic nervous system to the stimuli related to physical exercise, or that there was an additive effect of psychological and physiological factors on the system activation. The fact that the subjects' mood scores, assessed immediately after exercise were similar in both sessions speaks in favor of the former possibility.

The results presented in this paper were obtained in studies carried out exclusively under laboratory conditions. Therefore, they differ from those in which the plasma catecholamine changes were compared during exercise performed under various field conditions e.g. training exercise vs competition exercise (21). In the above investigations an excessive response of the plasma A, but not NA was reported during exercise in the stressful situations. A stronger and more prolonged psychological stress than that applied in the present study may be the reason of the exaggerated adrenaline vs noradrenaline response during exercise.

Summarizing

This study showed that a mild psychological stress, which worsens the subjects' mood does not cause any pronounced changes in heart rate, blood pressure, perceived exertion and blood lactate level during graded laboratory exercise test, but it does result in significant elevations in the plasma cortisol and noradrenaline concentrations.

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