ORIGINAL ARTICLE

The relation of cortisol and sex hormone levels to results of psychological, performance, IQ and memory tests in military men and women

Jaroslav Flegr [1], Richard Hampl [2], Dana Černochová [3], Marek Preiss [4], Marie Bičíková [2], Ladislav Sieger [5], Lenka Příplatová [1], Šárka Kaňková [1], Jiří Klose [6]

1 Faculty of Science, Charles University in Prague, Biology Dept., Prague, Czech Republic
2 Institute of Endocrinology, Steroid Depart., Prague, Czech Republic
3 Hogrefe-Testcentrum, Prague, Czech Republic
4 Prague Psychiat Ctr, Dept Biochem & Brain Pathophysiol, Prague, Czech Republic
5 Faculty of Electrical Engineering, Czech Technical University in Prague, Depart. Physics, Prague, Czech Republic
6 Central Military Hospital, Central Medical Psychology Dept., Prague, Czech Republic

Correspondence to: Jaroslav Flegr, PhD.
Dept. Philosophy and History of Science,
Faculty of Science, Charles University
Viničná 7, 128 44, Praha 2, Czech Republic.
TEL: +420 221951821; E-MAIL: flegr@cesnet.cz

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Abstract

BACKGROUND: Cortisol, along with other hormones of hypothalamo-pituitary-adrenal axis, belongs to one of the main factors influencing psychological and pathognomic factors, intelligence, and memory.
METHODS: The aim of our study was to review a large battery of psychological, performance, IQ and memory tests as to their relation with cortisol, testosterone and estrogen levels in groups of 100 men and 93 women who attended the Central Military Hospital in Prague for regular entrance psychological examinations for military personnel.
RESULTS: In men, we detected positive correlations between cortisol and emotional lability, and negative correlations with impulsivity, while in women hypochondria and psychopathology were negatively correlated, and aggression measured with the Meili selective memory test had a positive relation to cortisol level. Testosterone correlated positively with emotional liability and negatively with impulsivity in men, and negatively with hypochondria and psychasteny, indirect aggression, irritability and paranoia in women. Estradiol correlated positively with psychopathology in men, and negatively with phobia. It was positively correlated with negativism in women. No clear correlation was observed between the concentration of steroid hormones and psychomotor performance or intelligence.
CONCLUSIONS: Concentrations of steroid hormones correlate with results of several psychological tests, the sign and magnitude of these correlations, however, very often differ in military men and women.

INTRODUCTION

Cortisol, as one of principal stress hormones which, along with other hormones of hypothalamo-pituitary-adrenal axis, belongs to one of the main factors influencing psychological and pathognomic factors, intelligence, and memory. Though corticosteroids do not directly regulate behavior, they play crucial roles in fear and anxiety regulation. Glucocorticoids as well as mineralocorticoids induce chemical changes in particular sets of neurons via their receptors, thus contributing to certain behavioral outcomes. Both corticosteroids act in a cooperative way, influencing different aspects of fear at different phases of the stress response (Korte 2001). The reaction to stressful conditions and, more generally, to psychology, pathopsychology, intelligence and memory differ in males and females, which suggests the potential effects of sex hormones (Kajantie & Phillips 2006). Evidence has accumulated that the hypothalamo-pituitary-adrenal (HPA) axis may function differently in borderline personality disorder (BPD), a psychiatric diagnosis characterized by high exposure to stress, reactivity, and vulnerability to stress (Zimmerman & Choi-Kain 2009). Meta analyses have been undertaken recently of 66 journal articles that directly manipulated social stress or emotions and measured subsequent cortisol and also immune responses, taking into account various psychobehavioral aspects such as cognitive appraisals, basic emotions, rumination and worry, social threat, and global mood states (Denson *et al.* 2009). The conclusions were not unequivocal and were criticized as oversimplified due to their omission of certain outcomes (Miller 2009). Indeed, it is difficult to establish an integrated hypothesis from experiments with animals and psychological or behavioral tests in humans. On the other hand, psychological an performance tests and measurements of hormonal status may be useful in the selection of candidates for physically and psychologically extremely demanding occupations such as soldiers, pilots etc. (Taverniers *et al.* 2010; Taylor *et al.* 2007). The aim of our study was to review a large battery of psychological, performance, IQ and memory tests as to their relation with cortisol and steroid sex hormone levels in groups of healthy military men and women.

MATERIALS AND METHODS

Subjects

The study population consisted of 100 male and 93 female military personnel (mean age 27.9 years, s.d. 7.9 in men; 29.2 years, s.d. 7.3 in women) who attended the Central Military Hospital in Prague for regular entrance psychological examinations between 2009 and 2010 and consented to participate in the research project. The subjects were tested for RhD phenotype during the health examination and also provided 5 ml of blood for the steroid hormone essay. All study subjects were screened for health status prior to their enrolment in the study. In the informed consent form, the general aim of the project (a study of the influence of physiological traits on human psychology and psychomotor performance) and the need for obtaining their consent to using the results of their psychological and clinical examinations was explained to the subjects. About 65 % of the military personnel consented to the use of their test results for research purposes and provided 5 ml of blood for laboratory testing. The recruitment of study subjects and handling of data was performed in compliance with Czech law and approved by the Institutional Review Board of the Faculty of Science at Charles University.

Meili selective memory test

For the purposes of the present study, a computerized version of a selective memory test based on the Meili test (Meili 1961) was developed and used. The participants were asked to memorize the location of thirty simple pictures in a 6 × 5 grid. After sixty seconds (as indicated by the progress bar), the pictures disappeared from the grid and individual pictures began to be displayed for four seconds in the left corner of the monitor. The participants were requested to point out the cell of the grid in which the picture had originally been displayed (see Figure 1). Of the thirty pictures (stimuli), four items (9, 21, 24, 25) represented objects with aggressive and four (6, 7, 18, 29) with sadomasochistic themes (Jozífková & Flegr 2006). The output of the test was the number of correctly localized pictures and the fraction of aggressive and fraction of sadomasochistic items among correctly localized pictures.

TOPP – Test of attention and short term memory

This test is used to evaluate attention and short-term memory of operational character under time pressure. The touch screen is used during testing. The stimulation field is represented by columns of symbols compounded from numbers and letters that are spread across the screen according to a specific system which the participant is made aware of prior to the testing. The task of the participant is to look for the dictated symbol and mark it with the touch pen. After training, where the participant gets to know the pattern, 50 symbols are dictated. The speed of dictation is constant. The test is repeated three times. During each set the number of correct, wrong and skipped reactions is observed. The main output of the test is the number of correct reactions in three parts of the test, TCI-1, TCI-2 and TCI-3. It is therefore possible to find out the quality and dynamics of efficiency by comparing the performance during a single set and in all three sets in between. For the participants tested for the purposes of choice of profession, which also means participants with higher motivation to achieve better performance, this test can show not only the level of attention and short-term memory, but also the negative influence of emotion on performance.

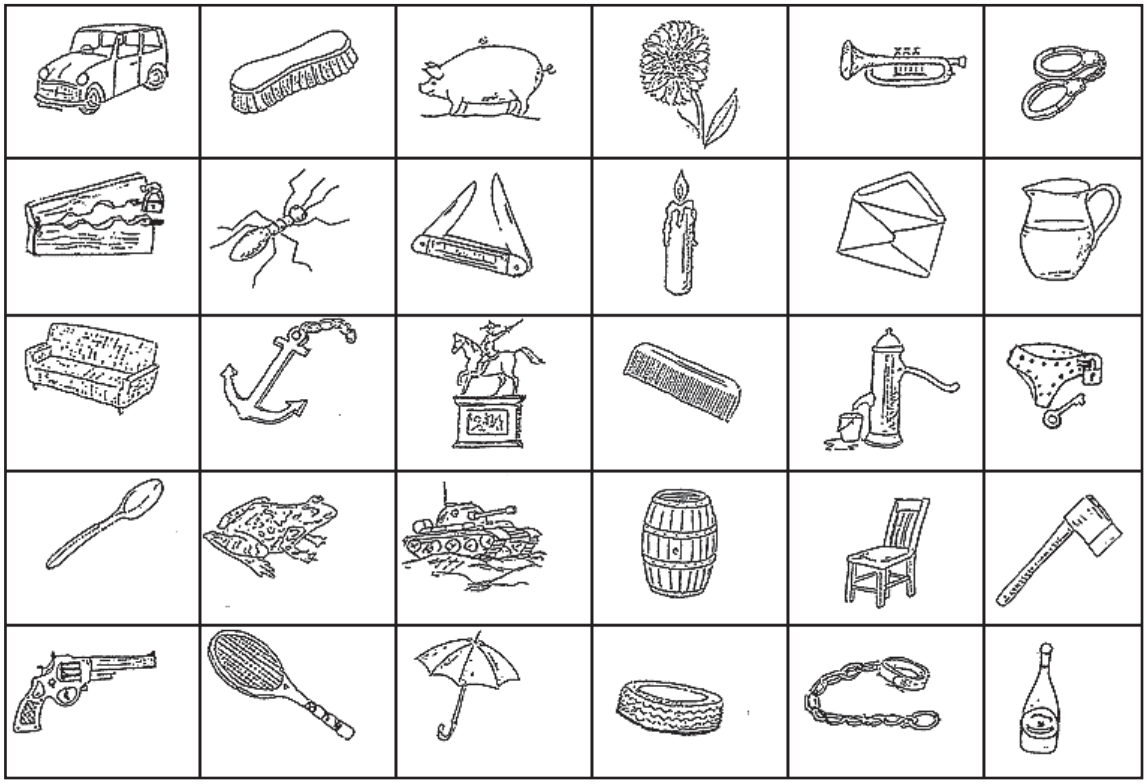

Fig. 1. Stimuli used in the Meili selective memory test. Of the thirty pictures, four items (9, 21, 24, 25) represented objects with aggressive and four (6, 7, 18, 29) with sadomasochistic themes.

N-70

The N-70 is a questionnaire constructed for the assessment of 7 areas of clusters – anxiety, depression, phobia, hysteria, hypochondria, psychosomatics symptoms and psychastenia. The purpose of this method is to detect individuals who may be too sensitive for military operations (Vacíř 1973). Subjects are asked to answer 70 questions using a 3-point agreement scale. Scores in each cluster range from 0–30. The total N-70 score is a sum of all clusters. The English translation of this questionnaire is provided in Appendix 1.

OD-1

This questionnaire covers the dimensions of the SPIDO questionnaire (Mikšík *et al.* 1991) that describes emotional characteristics of the individual, namely: EM, RG, ER, AD, KR and EA. Emotion (EM) measures the experiencing of emotions during interactions and situational changes. The dynamic of emotions and their consequences are considered. On the positive pole there is high excitability and a tendency to experience situational tension. On the negative pole there is emotional stability up to lowered emotivity. Regulation (RG) refers to behavioral regulation and activity control. High values mean low self-control and low consideration of possible consequences. The opposite values represent anticipation of behavior. Impulsivity (ER) characterizes impulsivity of falling for immediate impressions when values are high, and self-control and judicious behavior when values are low. A high value of the next trait, the Adaptability (AD), is characteristic of subjects who easily and willingly adapt to conditions, up to submissive stands in extremes. The individual scoring on the opposite pole has, on the contrary, a tendency to persist in his behavioral schematics and to request adaptation of surroundings. Risking (KR) reflects the tendency towards risk. High values represent immediate action coming from a sudden idea, without considering the impact of possible failure. Low values mean persistent consideration of consequences up to almost inactive, very careful and restrained behavior. Enthusiasm (EA) reflects position on the optimism-pessimism axis. On the positive pole this means satisfaction, optimism, enthusiasm; on the negative pole it means pessimism, disappointment, and low self-confidence. Psychopathology (PP) scale was added to the OD-1 questionnaire; it is not contained in the SPIDO questionnaire. PP scale was composed of items that measure various personality psychopathology characteristics, see Appendix 2.

BDI (Buss-Dürker Inventory)

For a measurement of physical, verbal and indirect aggressivity, irritability, negativism, resentment, guilt and paranoia, we used the Buss-Dürker Inventory (Buss & Durkee 1957). In the Czech version of the questionnaire (Svoboda 1999), we replaced a categorical way of answering the items (yes/no), with a 5-grade scale

from "absolutely agree" to "absolutely disagree", which is better suited to testing subjects who are highly motivated to successfully pass psychological examinations.

WMT

The Wiener Matrizen-Test WMT, (Formann & Piswanger 1979), a non-verbal intelligence test, is an adapted version of the Raven progressive matrices which conforms to the Rasch model (Rasch 1960). The WMT assesses general intelligence by measuring reasoning ability. The test requires the completion of 24 matrices with increasing task difficulty and was administered without an explicit time limit. The intention and conceptualization of the WMT are largely based on Raven's Matrices (Raven 1947; 1958a;b). The correlation between the WMT and Standard Progressive Matrices is about r = 0.92 (Formann & Piswanger 1979). Construction and item selection, however, follow the standards of Rasch scaling. For these reasons, and due to the fact that the WMT showed comparable validity characteristics but had a considerably higher administration economy, we prefer the WMT to the Raven matrices in clinical practice. The split-half reliability of the WMT is 0.83(Formann & Piswanger 1979). The 1993 Czech adopted version (Klose *et al.* 2002), distributed by Psychodiagnostika (Brno), was used in the present study. Both the raw score and the IQ (adjusted for age of the participant based on results of 2007 survey performed in Central Military Hospital: age 15–20, N=1 232, mean=16.33, S.D.=4.33; 21–30, N= 4 551, mean=15.99, S.D.=4.32; 31–40, N=2 482, mean= 15.66, S.D.=4.38; 41–50, N=569, mean=15.02, S.D.=4.46; higher than 50, N=31, mean=11.81, S.D.=4.89) were compared in statistical tests.

OTIS

The test of verbal intelligence which was derived from the original test (Otis 1954). Seven types of items were taken from the original test:

- term or object definition by choosing the most suitable characteristics
- term or object definition by choosing the most suitable description
- the choice of an object based on common attributes
- the choice of the opposite
- the identifying of "foreign" (unrelated) term
- logical resp. ethical solution of the situations
- the interpretation of the adage

The test contains 32 items (0–32). The maximum score is therefore 32 points. Norms for computing IQ values were created in the Central Military Hospital in Prague in a separate large scale study for the Czech population. This study included 1 470 subjects with elementary education (mean score=19.47, S.D.=4.92), 1 225 subjects with secondary school education (mean score=24.15, S.D.=4.21), and 403 subjects with higher school education (mean score=26.62, S.D.=3.09). Both the raw score and the IQ (adjusted for the achieved educational level of a proband) were compared in statistical tests.

Steroid hormone determination

Cortisol: Serum samples, 20 µl, were diluted with 0.1 M sodium phosphate-citrate buffer, pH 4 containing BSA and sodium azide (0.1% each) to final volume 400 µl in plastic eppendorf tubes, and measured by radioimmunoassay kits Spectria from Orion (Finland). The range of physiological levels from morning sampling for both males and females, determined in the author´s laboratory, were 138–607 nmol/l.

Testosterone was determined by radioimmunoassay after the extraction of 100 µl serum samples with diethyl ether, using kits from Immunotech (Beckman Coulter, Czech Division, Prague). The range of physiological levels from morning sampling for the age groups studied, as determined in the author´s laboratory, were 10–34 nmol/l and 0.40–3.00 nmol/l for males and females, respectively.

Estradiol was determined in 100 µl serum samples without extraction, using radioimmunoassay kits Spectria from Orion (Finland). The range of physiological levels from morning sampling, determined in the author´s laboratory were 0.01–0.23 nmol/l and 0.09–1.29 nmol/l for males and females, respectively. The levels of estradiol in women varied considerably during the menstrual cycle.

In all cases where an analyzer, Stratec (Immunotech, Prague), was used for analyses, the analytical criteria (sensitivity, precision, accuracy) agreed with those reported by the manufacturers. For other details of the laboratory procedures also see (Flegr *et al.* 2008).

Statistical analysis

The Statistica 6.1 and SPSS 16.0 programs were used for statistical testing (frequency tables, logistic regression and the Generalized linear model) and to check statistical test assumptions. Partial correlation Kenadall test was used for nonparametric analyses (Kaňková *et al.* 2010) ; the Excel sheet for this analysis is available at http://web.natur.cuni.cz/flegr/programy.php. All variables including the covariates entered in the respective analyses are specified in the Results section.

RESULTS

The total experimental set contained 93 women and 100 men; however, only some subjects were tested with all tests (see Table 1). Women and men differed in some psychological and pathognomic factors; for results of t-tests and descriptive statistics see Table 1. Since the concentrations of hormones differ between men and women, both sexes were analyzed in separate tests. Most of the monitored psychological traits changed with the age of the subjects. Therefore, we controlled the data for the effects of age using partial correlation Kendall tests with the age of the subjects as a covariate.

Tab. 1. Descriptive statistics of population and differences between men and women.

Test / parameter	WOMEN			MEN			SEX DIFFERENCES	
	n	Mean	S.D.	n	Mean	S.D.	t	*p*-value
Age	100	29.25	7.87	100	27.95	7.95	–1.181	0.239
Total N70 score	90	19.92	9.56	93	18.76	10.9	–0.797	0.426
Anxiety N70	90	5.36	2.45	93	4.6	2.39	–2.107	**0.037**
Depression N70	90	2.44	2.19	93	2.16	1.96	–0.922	0.358
Phobia N70	90	2.71	1.84	93	2.68	1.92	–0.121	0.904
Hysteria N70	90	2.44	1.6	93	2.85	1.73	1.641	0.102
Hypochondria N70	90	2.13	1.97	93	2.29	1.82	0.56	0.576
Vegetative lability N70	90	3.69	2.4	93	3.24	2.61	–1.305	0.193
Psychasteny N70	90	2.29	2.49	93	2.13	2.16	–0.464	0.643
Emotions OD-1	88	4.82	4.51	93	5.15	4.64	0.488	0.626
Regulation OD-1	88	7.11	1.1	93	6.26	2.37	1.684	0.094
Adaptability OD-1	88	14.91	2.35	93	15.44	2.76	1.391	0.166
Risking OD-1	88	3.10	1.76	93	4.22	2.17	4.085	**0.000**
Enthusiasms OD-1	88	3.68	2.24	93	3.81	2.45	0.356	0.722
Impulsivity OD-1	88	10.14	1.37	93	10.15	1.44	0.068	0.946
Psychopathology OD-1	88	1.57	1.56	93	3.28	3.17	4.571	**0.000**
Physical aggression BDI	28	18.11	7.37	82	24.1	7.32	3.679	**0.000**
Indirect aggression BDI	28	25.14	7.69	82	23.99	7.55	–0.697	0.487
Irritability BDI	28	22.52	7.27	82	20.64	7.16	–1.196	0.234
Negativism BDI	28	21.5	7.88	82	22.1	9.18	0.308	0.759
Resentiments BDI	28	20.0	7.93	82	21.39	8.94	0.729	0.468
Paranoia BDI	28	24.75	1.6	82	27.17	9.28	1.276	0.205
Verbal aggression BDI	28	33.88	7.35	82	33.56	5.66	–0.238	0.812
guilty feelings BDI	28	30.72	8.7	82	29.85	9.60	–0.445	0.657
total memory Meili score	28	10.25	3.88	73	9.25	4.40	–1.13	0.261
aggression Meili score	28	0.13	0.08	73	0.16	0.11	1.349	0.181
SM Meili score	28	0.14	0.07	73	0.18	0.10	2.005	**0.048**
Otis raw intelligence	88	18.22	6.17	93	22.94	5.27	5.546	**0.000**
Otis IQ	88	101.67	13.4	93	100.72	16.26	–0.432	0.666
WMT raw intelligence	86	21.88	5.64	93	14.13	4.35	–10.341	**0.000**
WMT IQ	86	103.21	11.69	93	100.24	15.84	–1.419	0.158
TCI-1	89	40.27	9.661	93	35.8	1.60	–3.581	**0.000**
TCI-2	89	41.94	8.208	93	38.43	1.60	–3.156	**0.002**
TCI-3	89	43.94	8.073	93	40.16	6.18	–3.538	**0.001**
cortisol (nmol/l)	93	728	121	100	505	353	–5.953	**0.000**
testosterone (nmol/l)	93	1.10	3.868	100	15.53	0.594	34.59	**0.000**
estradiol (nmol/l)	93	0.29	0.029	100	0.11	0.342	–5.28	**0.000**

Significant differences ($p<0.05$) between men and women are printed in bold.

The differences in psychological traits between men and women are shown in Table 1. In men, higher scores than in women were found in anxiety, propensity to risk taking, overall aggressivity, risk, psychopathology, physical aggression, SM Meili score and Otis intelligence. Significantly higher scores in women were recorded in anxiety, WMT intelligence, TCI-1, TCI-2 and TCI-3. The levels of sex hormones corresponded to known values for both sexes in the studied age groups, while the level of cortisol was higher in women.

Table 2 shows the correlations between traits measured with psychological tests and steroid hormone concentrations. In women, significant negative correlations with cortisol were found in hypochondria (N-70 test) and psychopathology in OD-1 test, while a positive correlation was found with the aggression score in the Meili test. Negative correlations with testosterone were recorded with hypochondria and psychasteny in N-70 test and in three traits of BDI test, namely indirect aggression, irritability and suspiciousness. Estra-

Tab. 2. Correlation between results of psychological tests and hormone concentrations.

	WOMEN						MEN					
	cortisol		testosterone		estradiol		cortisol		testosterone		estradiol	
	Tau	*p*-value	Tau	*p*-value	Tau	*p*-value	Tau	*p*-value	Tau	*p*-value	Tau	*p*-value
N70 test												
total score	–0.079	0.271	–0.082	0.252	0.013	0.853	0.023	0.747	–0.007	0.915	–0.017	0.810
anxiety	–0.071	0.323	–0.063	0.378	0.081	0.261	0.036	0.613	–0.018	0.800	–0.026	0.717
depression	–0.082	0.253	–0.074	0.303	0.083	0.244	0.050	0.477	0.059	0.403	–0.107	0.130
phobia	0.072	0.316	0.072	0.314	–0.142	**0.047**	0.078	0.269	0.098	0.164	0.058	0.407
hysteria	–0.083	0.245	0.037	0.604	0.018	0.801	–0.068	0.333	0.007	0.926	0.002	0.973
hypochondria	–0.141	**0.049**	–0.142	**0.048**	0.060	0.401	0.037	0.598	–0.043	0.546	–0.059	0.405
vegetative lability	–0.139	0.053	–0.091	0.206	0.036	0.614	0.044	0.528	–0.015	0.829	0.069	0.327
psychasteny	–0.057	0.430	–0.144	**0.045**	–0.005	0.941	–0.010	0.886	–0.017	0.807	–0.072	0.309
OD1 test												
emotion	–0.031	0.669	–0.006	0.934	0.016	0.822	0.151	**0.032**	0.025	0.725	0.112	0.111
regulation	0.012	0.873	–0.022	0.758	–0.015	0.833	–0.018	0.794	0.090	0.201	0.026	0.710
adaptability	0.099	0.173	0.031	0.672	–0.053	0.465	–0.050	0.477	–0.006	0.937	–0.052	0.459
risking	0.038	0.599	0.071	0.326	–0.023	0.746	0.046	0.512	0.052	0.462	0.099	0.159
enthusiasm	–0.002	0.974	–0.016	0.830	0.041	0.573	0.090	0.200	0.112	0.111	0.019	0.790
impulsivity	0.126	0.082	0.049	0.498	–0.076	0.297	–0.162	**0.021**	–0.063	0.371	–0.025	0.723
psychopathology	–0.198	**0.006**	–0.022	0.765	0.107	0.140	0.122	0.084	0.233	**0.001**	0.159	**0.024**
BDI test												
physical aggression	0.068	0.612	–0.211	0.114	–0.049	0.717	0.061	0.416	0.065	0.388	0.041	0.589
indirect aggression	–0.179	0.181	–0.319	**0.017**	0.038	0.779	0.013	0.858	–0.023	0.755	0.052	0.486
irritability	–0.255	0.057	–0.358	**0.007**	0.159	0.234	0.028	0.707	0.036	0.634	0.019	0.799
negativism	–0.244	0.068	–0.102	0.447	0.266	**0.047**	–0.086	0.252	–0.006	0.934	–0.024	0.750
resentiments	–0.243	0.069	–0.139	0.300	0.195	0.146	0.091	0.225	0.110	0.145	0.112	0.135
paranoia	–0.054	0.685	–0.334	**0.013**	–0.094	0.480	0.081	0.284	0.148	**0.049**	0.127	0.091
verbal aggression	–0.079	0.554	–0.172	0.200	0.000	0.998	0.120	0.112	–0.014	0.849	–0.054	0.475
guilty feelings	–0.139	0.298	–0.056	0.673	0.031	0.815	0.104	0.167	–0.008	0.919	0.030	0.692
Meili test												
total memory score	0.238	0.075	0.145	0.277	–0.258	0.054	–0.062	0.435	0.001	0.992	0.005	0.946
aggression score	0.301	**0.025**	–0.031	0.819	–0.234	0.081	0.051	0.526	0.105	0.187	0.015	0.846
SM score	0.065	0.628	–0.018	0.892	–0.182	0.173	–0.156	0.052	–0.137	0.086	–0.095	0.234

Significant correlations and trends ($p<0.1$) between psychological factors and performance and hormone concentrations are printed in bold. Positive and negative Tau (reflecting the effects size) means positive and negative correlation, respectively.

diol correlated negatively with phobia (N-70 test) and positively with negativism in the BDI test. In men, cortisol correlated positively with emotional liability and negatively with impulsivity (both measured with OD-1 test). Testosterone correlated positively with psychopathology (OD-1 test) and with paranoia in the BDI test. Only one trait was positively correlated with estradiol, namely psychopathology in OD-1 test. No clear correlation between the concentration of hormones and the performance of subjects measured with the TOP test and intelligence tests was observed. Furthermore, performances in the 1st, 2nd and 3rd minute of the TOPP test were analysed by repeat measurement of GLM with a logarithm of hormone concentration and age of subject as independent variables. No correlation was observed between results of TOPP and concentration of cortisol or estradiol, however, the interaction between minute of the test and testosterone concentration was significant both for men (p=0.018, η^2=0.044) and women (p=0.043, η^2=0.036). In women, only an insignificant negative correlation between testosterone concentration and number of correctly localized targets was observed in the first part of the TOPP test and no correlation was observed in the second and third minute of the test. In men, no correlation between testosterone concentration and number of correctly localized targets was observed in the first minute of the TOPP test and only insignificant negative correlation in the second and third minute of the test. No association was observed between intelligence and level of hormones, except a negative association between intelligence and testosterone concentration in men quantified with repeatedly measured GLM, using IQ estimated with OTIS and WMT tests as repeated measures and a logarithm of testosterone and age of subjects as independent variables (p=0.047, η^2=0.043).

DISCUSSION

Sex differences in psychobehavioral traits such as a higher tendency towards risk taking, aggressiveness, and propensity to personality psychopathology in men correspond to known differences in male and female psychology (Korte 2001). Of interest is the higher anxiety score in women, which was recently reported as one of the paradoxical effects of steroid modulation of $GABA_A$ receptors (Andreen *et al.* 2009). Differences in sex hormone levels between males and females are well known, as well as the fact that these levels are strongly influenced by the phase of the menstrual cycle in women. Rather surprising were the higher levels of cortisol in women, which could be ascribed to oral contraceptives or, in later age, to hormone replacement therapy, the information of which was lacking in our records. Higher cortisol levels could thus be a consequence of the impact of estrogen on transcortin formation and, more generally, on hypothalamo-pituitary control of steroid secretion. However, it can be speculated that the higher level of cortisol in women may be caused by higher levels of chronic stress in female military personnel (see below).

In this paper a large battery of psychological tests was performed and the data were correlated with actual cortisol and sex steroid levels. The aim was, among others, to evaluate the usefulness of cortisol and sex steroid hormone determination in the selection of candidates for professional military service. The results differed considerably between men and women. While in men the only significant correlations with cortisol were recorded in the test expressing emotional lability and impulsivity, there were three traits (hypochondria in the N-70 test, psychopathology in OD-1 test and aggression in Meili test), which were related to cortisol in women.

A high concentration of cortisol is characteristic of subjects under chronic stress. It was recently shown (Flegr & Příplatová 2010) that the concentration of cortisol (as well as testosterone) increases in female and male university students that achieved good results in a written exam. At face validity, the nature of the psychological traits of a female with a higher concentration of cortisol, i.e., decreased N-70 hypochondria score and OD-1 psychopathology score, and increased Meili aggressivity score, suggest that good feelings from the absolved tests, rather than chronic stress, were responsible for the observed association. It must be considered, however, that the level of cortisol was measured before the psychological and psychomotor performance testing in the present study. Therefore, chronic stress rather than positive feelings after the test was responsible for the observed associations. In contrast to men, who seem to use more individualistic and antisocial (e.g. aggressive, hostile) forms of coping with stress (Carver *et al.* 1989; Hobfoll *et al.* 1994), women are more likely to seek and provide social support (Carver *et al.* 1989; Stone & Neale 1984; Rosario *et al.* 1988), join with others (Hobfoll et al 1994), and verbalize towards others or the self (Tamres *et al.* 2002). This can result in seemingly more desirable personality traits observed in high-cortisol (chronically stressed) women (Lindová *et al.* 2010).

Concerning testosterone, of interest may be the highly significant positive correlation with inclination to psychopathology and related paranoia in men, while in women there were as many as five traits (N-70 hypochondria and psychastenia, BDI indirect aggressivity, irritability and suspiciousness) negatively correlated with testosterone. Of those, paranoia correlated with testosterone in both sexes, but negatively in women and positively in men. Generally, the psychological profile of high-testosterone women expressed more desirable character traits than that of low-testosterone women. With one exception (psychopathology), no trait correlated with estradiol in men. The former corresponds to the fact that estradiol in males is synthesized from testosterone. The data on estradiol association with psychological traits in women couldn't be evaluated in

the present study due to their being influenced by the menstrual cycle and the possible use of contraceptives.

In contrast with previous results (Flegr *et al.* 2008c), we did not detect a strong positive effect of testosterone concentration in the results of the psychomotor performance test in men. However, the simple reaction test was used in the original study while a more complex TOPP test was used in the present study. It is possible that the higher competitiveness of high testosterone men (Archer 2006), rather than higher psychomotor performance, is responsible for their better results in the simple reaction time test. It is, however, also possible that differences between older and newer studies resulted from the statistical control of some important confounding variables, such as Rh blood group factor and toxoplasmosis infection, which are known to strongly influence the results of psychomotor performance tests (Flegr *et al.* 2008c; Havlíček *et al.* 2001; Novotná *et al.* 2008) or levels of testosterone in the human organism (Flegr *et al.* 2008a;b; Hodková *et al.* 2007).

The first studies of the relation of psychological tests to cortisol and testosterone appeared as early as the 1980s (Francis 1981), and confirmed that men under psychological stress, as reflected by high cortisol, had significantly lower testosterone levels. Later studies have shown that personality traits were (also) associated with different cortisol responses to stress due to altered function of the HPA axis (Oswald *et al.* 2006). Various personality measures of negative affectivity have been associated with high cortisol levels, but so have measures of positive social adaptation and agreeableness (Tops *et al.* 2006). Our results are in agreement with some of the data reported and, in any case, confirm the importance of cortisol and eventually testosterone measurement along with psychological tests. On the other hand, the determination of estradiol in men is of much less importance and in women its importance is strongly limited by estradiol fluctuation during the menstrual cycle phase and also by use of contraceptives. An important limitation of the present study is the moderate number of subjects. Despite the relatively strong effect size of some correlation (estimated on the basis of Kendall Tau), the statistical significance was relatively low because of the high variability of hormone concentrations and personality traits in the normal human population. With the exception of a correlation between psychopathology (OD-1) and concentration of testosterone in men, no other significance would survive correction for multiple tests. Therefore, the present study must be considered an exploratory study and the observed phenomena should be confirmed in other populations in the future.

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Appendix 1

The N-70 questionnaire constructed for the assessment of 7 areas of clusters – anxiety (1–10), depression (11–20), phobia (21–30), hysteria (31–40), hypochondria (41–50), psychosomatics symptoms (51–60) and psychastenia (61–70). Subjects are asked to answer 70 questions using a 3-point agreement scale (often- 2, sometimes- 1, never- 0). Scores in each cluster range from 0–30. The total N-70 score is a sum of all clusters.

1. Do you feel anxious when your superior calls you and you don't know why?
2. Do you experience uncomfortable inner tension such as if something bad is going to happen?
3. In demanding situations, do you feel butterflies in your belly or chest; do you need to go to the toilet more often?
4. Do you suffer from stage fright?
5. Do you suffer from fear that is unproportional to the situation from which it originates?
6. Do you feel like vomiting when expecting trouble?
7. Do you comfort eat when you are sad or worried more than other people?
8. Do you suffer from indeterminate fear despite having no reason for such worries?
9. Do you feel unpleasant thumping of your heart when confronted with a distressing situation?
10. Do you suffer from any agitated states when you cannot hold still, you must keep moving or do something without purpose, e. g. chain smoking?
11. Have you been lately easily depressed?
12. Do you ever feel like you have lost your ability to have fun, revel, or look joyfully to the future?
13. Do you think that you are an unhappy person?
14. Do you have problems controling tears in harming situations?
15. Do you have black thoughts; are you unable to get rid of them?
16. Do you feel that your interest in things that you were earlier interested in has decreased because of sad moods?
17. Does sadness or joyless mood decrease your working performance?
18. Do you have problems to get asleep in the evening because you are unable to get rid of distressing thoughts?
19. Do you feel that your friends avoid you though you haven't done them anything bad?
20. Have you been experiencing suicidal thoughts lately?
21. Do you often have thoughts about you suffering from some severe illness or the possibility of acquiring one?
22. Do you suffer from irrational fear in closed spaces?
23. Do you have strong fear of heights, are you afraid of fall or – when high above – is something inside tempting you to jump down?
24. Do you suffer from strong anxiety in crowded places?
25. Do you suffer from an uneasy feeling that you forgot some of your domestic tasks (such as closing windows, locking doors, switching off lights)?
26. Do you often have nonsensical ideas such as to count windows, to walk only on specific cobblestones, or to say inappropriate words in stresful situations?
27. Do you often have inappropriate thoughts that you don't agree with and that are difficult to get rid of?
28. Do you often have to double check your previous tasks to get calm and to be reassured that you did them right?
29. Do you get severely out of balance when your daily habits are disturbed?
30. Do you think that you are a perfectionist? Do you hate when something is done imprecisely or if there is not absolute order around you?
31. Do you feel like fainting when you are strongly keyed up?
32. Do you feel good when you are the center of attention?
33. Do you feel pins and needles or loss of sensitivity in some places when you are strongly keyed up?
34. Do you have problems to control your limbs because of strong excitement?
35. Do you feel that you can't stop yourself when you are upset despite unconsciously feeling that you are acting wrongly?
36. Are you ever unable to talk as if your tongue is numb in unpleasant situations?
37. Do you like dramatic situations when you have a chance to show off?
38. Do you have spasms in your limbs during conflict situations?
39. Do you ever feel that you have tendencies to sham and pretend?
40. Do you ever deceive other people to achieve your own goals?
41. Do you often feel ill?

Appendix 1 *cont.*

42. Do you obsess over health problems?
43. Do you often visit a physician even with minor problems?
44. Do you check your body temperature, pulse, face in mirror etc. when feeling sick?
45. Do you try to educate yourself when diagnosed with a health problem (by reading popular medical articles or books)?
46. Are you always well aware of the hidden propaganda in things you read?
47. Do you suffer from indigestion?
48. Do you have diarrhea or constipation?
49. Do you ever suffer from a general feeling of pain or discomfort in your muscles or joints?
50. Do you confide your problems to your acquaintances and/or friends?
51. Do you suffer from full body excess sweating or sweating of your hands and/or feet?
52. Do you suffer from headaches?
53. Do you feel like your heart sometimes skips a beat?
54. Does your heart flutter or start to race easily in demanding situations?
55. Do you blush easily?
56. Do you always feel cold?
57. Do you feel that you have difficulties with breathing even when relaxing?
58. Do you suffer from vertigo or dizziness?
59. Do you feel like vomiting when you see something disgusting or if you hear someone talking about detestable things?
60. Do you feel nauseous before common dental or medical interventions and minor surgical procedures?
61. Do you suffer from inner disquiet, tension, or restlessness?
62. Do you think that your memory isn't as good as it was?
63. Do you think that you are less tolerant to noise and rush in your surroundings lately?
64. Do you feel weariness and exhaustion that doesn't correspond with your working load?
65. Do you feel very weak (like after suffering longterm ilness)?
66. Do you feel that your sexual appetite is diminishing, do you have problems in sexual intercourse that you didn't have before?
67. Do you have a short fuse, do nonessential things that get you out of balance?
68. Do you feel that you don't work as effectively as before and that your performance is worsening despite all your efforts?
69. Do you tire more quickly than before?
70. Do you sleep badly; do you wake up feeling that sleep didn't refresh you?

Appendix 2

Psychopathology (PP) scale of the OD-1 questionnaire was composed of following items (the numbers mean the position of particular item in the questionnaire):

3 - I do a lot of things that I lately regret to have done and I do them a lot and probably more often than other people.
6 - I would be far more successful in my life if it wasn't for people who crimped me.
7 - I think that my family life is not that pleasant as that of the most of the people I know.
9 - Sometimes I really wanted to leave home.
11 - One of the best ways of dealing with problems is not to think about them.
14 - One may work as hard as he wants to but he will not reach his goals anyway.
17 - In comparison with other families there is not as much of love and coherence in mine.
19 - I think there's a multitude of people who try to avoid me.
21 - I never mind being often involved in arguments.
23 - My friendships tend to break often and it's not my fault.
25 - I act in a way that people easily misunderstand my actions.
27 - My parents and my family criticize me more than it's necessary.
28 - I often feel that I did something wrong or bad.
36 - There are people who want to disserve me.
38 - I have a desire to break, crush and destroy things and it's an inherent part of myself.
45 - I'm used to think of or need to hit, harm or injure someone.
50 - I can easily bear to witness someone hitting a child or abusing an animal.
55 - It makes me feel good to hurt even those people that I like.
57 - I haven't lived a rightful life.
59 - Sometimes I like to annoy people that hurt me or didn't do what I wanted.
61 - I don't abide rules because they misguide me in a way.
68 - In childhood I wanted to be a member of a group or a gang that goes through various adventures.