Should be cited as: Psychiatria Polska
2012, tom XLVI, numer 5
strony 731–740

An influence of mental stress related to parachute jumping on ACTH and cortisol levels in blood serum

Edward Kowalczyk[1], Marcin Kura[2]

[1] Department of Pharmacology and Toxicology of Medical University in Łódź
Head of the department: dr hab. n med. E. Kowalczyk, prof. UM
[2] Team of Medical Security – 16th Air-Borne Battalion in Cracow, Poland
Team commander: dr n. med. M. Kura

Summary

Aim. The purpose of this research was to estimate the influence of parachute jumps on the level of corticotropin (ACTH) and cortisol hormones among professional soldiers from air-borne forces.

Method. The study was carried out on 46 professional soldiers from 16 Air - Borne Battalion, patients of Outpatient Department – SPZOZ JW. 4495 males, at the age of 20 to 45, healthy – admitted to parachute jumping in air – borne forces. The soldiers were divided into groups according to their knowledge and experience in parachuting. They had circuit venous blood taken to examine the level of ACTH and cortisol hormones three times during the experiment: on a day free from jumping, on the day of parachute jump, and 24 hours after the jump. Additionally, in order to estimate the level of nervous tension and mental stress, on every stage of the experiment personal questionnaires in accordance with the STAI were carried out.

Results. The results show the influence of psychological stress related to parachute jumps on the level of ACTH and cortisol hormones, depending on the experience of the examined group in parachuting.

Key words: ACTH, cortisol, psychological stress

Introduction

The concept of stress occurs in science in two different meanings - as physiological and psychological stress. Physiological stress is a set of general adaptive changes in response to a new factor that appears in the organism or the environment. This set includes, inter alia, intensification of the processes of metabolism, increase of blood pressure and heart rate, increase of blood sugar level, growth of body temperature, secretion of antibodies, increase of blood coagulability [1].

The study was funded by the Ministry of Science and Higher Education under the contract number 1152/B/T00/2009/36 on the realization of research PhD project No O N402 115236.

The physiological stress response involves two biological systems - the sympathetic nervous system, which is activated first, and the system of the hypothalamus-pituitary -adrenal axis, which starts working after a while.

The sympathetic nervous system, as part of the autonomic nervous system, is responsible for the so-called fight or flight response. In the first moments after the activation of the stressor, it stimulates the adrenal glands to secrete adrenaline and noradrenaline. It evokes such effects as heart rate and breathing acceleration, faster and more efficient heart function, bronchodilation and pupils widening. This results in a decomposition of fat into fatty acids and glycerol, the decomposition of glycogen stored in the liver to glucose and the centralization of circulation.

The hypothalamic-pituitary-adrenal axis is activated only after minutes or hours after the stressor influence. Cortisol increases the level of glucose in the blood and accelerates the decomposition of fatty acids into ketones. It also changes the processing of information that reach the sense organs. It reduces the sensitivity of the senses, namely the ability to receive even the weakest stimuli, and enhances the ability to distinguish separate stimuli.

Because during the stress response the sympathetic nervous system works first and then the hypothalamic-pituitary-adrenal gland axis, in majority of people short-term stress does not increase the level of cortisol (the speed and easiness of response of the hypothalamic-pituitary-adrenal gland system is individually variable, and in some persons even short-acting stressors increases the concentration of cortisol).

Adrenaline, noradrenaline and cortisol are the main, but not the only, hormones involved in stress reaction. It also involves endorphins and encephalin that reduce the perception of pain, thyroxine accelerating energy stored in fat, aldosterone raising blood pressure, as well as melanotropin, thyroid stimulating hormone, vasopressin, renin, growth hormone, glucagon, prolactin, parathyroid hormone, calcitonin, gastrin and many others [1].

Psychological stress is a change that occurs in the psychological regulatory mechanisms and activities under the influence of various difficult situations. Stressor can be any stimulus or situation constituting an obstacle or interruption of activity performed on purpose, any loss, injury or illness, and even a signal of threat.

The psychological stress complex includes processes of the body mobilization (as in physiological stress) and increase of the level of activation, namely an overall increase in the central nervous system arousal. It is manifested in acceleration of the process of reception and processing of information, and increased tendency to react, the psychological equivalent of the state of mental alertness or arousal.

Stress situations are accompanied by strong emotional arousal. They evoke tension, insecurity, anxiety, fear, grief, sadness, anger. Such experiencing can be called distress, or bad stress, caused by too strong stimulation or inadequate arousal. The balance between psyche and somatics is disturbed.

Is also happens sometimes that in a stressful situation pleasurable excitement, interest, enthusiasm, energy flow are experienced. This positive variation of stress is called eustress, or a good state of mental and physical well-being in which the mind and body reach their full potential [2].

The purpose of the study was to evaluate the impact of parachute jumping on the levels of hormones: cortisol and corticotropin in blood serum.

Material and methods

The investigation was carried out on 46 professional soldiers from 16 Air - Borne Battalion, patients of outpatient department – SPZOZ JW. 4495, healthy males at the age of 20 to 45 – admitted to perform parachute jumping in air – borne forces.

They were divided into 5 groups:

1) Professional soldiers performing their first jump (7 persons);
2) Professional soldiers during their first season of jumping, performing for the first time a standard of at least 5 jumps per year (14 persons);
3) Professional soldiers with the parachutist title, performing regularly at least 5 parachute jumps per year (13 persons);
4) Parachute instructors, performing at least 20 parachute jumps per year (7 persons);
5) The members of the parachute sport group performing competitive parachuting (5 persons).

The groups corresponded to the knowledge and experience in performing parachute jumps. Additionally, in order to emphasize the differences in experience, a division of the total sample into two groups was done - depending on the number of parachute jumps already performed:

1) Parachute jumpers having already up to 20 jumps performed;
2) Parachute jumpers having already more than 20 jumps performed.

Three times during the experiment the participants had about 10 ml of their peripheral venous blood taken, on an empty stomach, in order to make assays:

on the normal working day (trial)
on the day in which the parachute jump was performed (jump)
one day after parachute jump (24 hours after the jump).

The dates of performing the assays were to reflect the initial balance of the organism, the state at the time of stressor acting and its effects on the body system.

In order to assess the level of emotional tension, each soldier taking part in the study completed a personal questionnaire based on the „State-Trait Anxiety Inventory" of the Psychological Test Laboratory. Surveys were carried out in cooperation with the person responsible for psychoprofilaxis in the Military Unit. The soldiers completed the survey three times - on a non-jumping day (trial), just before the jump, and 24 hours after jump. The Polish version of the Inventory (ISCL) is an adaptation of the American State-Trait Anxiety Inventory (STAI) developed by Spilberger CD, RL Gorsuch and R. E. Lushene [3].

Determination of the hormones level - adrenocorticotropic hormone and cortisol - was performed in the Medical Laboratory „Diagnostyka Sp z o. o." (Diagnostics LLC)

in Cracow. To eliminate the influence of circadian rhythm on the levels, the venous blood samples were collected at the same times of the day. In addition, to exclude homeostasis disorders, especially inflammation, the basic blood cell indicators were checked, the level of acute-phase protein - CRP and basic biochemical indicators. Assays of these parameters hava also been made in the above laboratory.

Statistical analysis of the results was made at the Laboratory of Bioinformatics and Biostatistics - BioInforStats in Cracow, using statistical package STATISTICA for Windows. The significance of the difference of distributions between the groups was analyzed using Kruskal-Wallis test and the significance of differences between individual assays in time was analyzed using Friedman test. The significance of the difference in distribution of results depending on the group in terms of the number of jumps was analyzed using the Mann-Whitney U test, and the significance of differences between individual assays in time were analyzed using Friedman test. As significant was considered the test probability at the level of $p \leq 0.05$, and as highly significant $p \leq 0.01$. The research project was approved by the Bioethics Commission of the Medical University of Łódź (Resolution No. RNN/430/07/KB dated 24.07.2007) and the Commission of Bioethics of the Military Medical Association (Resolution No. 61/08 dated 14.03.2008).

Results

It was found that for the soldiers participating in the study, according to the personal surveys and on the basis of the Polish version of the "State-Trait Anxiety Inventory", the parachute jump is an important stress stimulus, especially for the less experienced soldiers in performing parachute jumps. In addition, the stressful stimulus, which is parachute jumping, negatively affects the individual tendency to anxiety (stress) behaviors and increases susceptibility to stress (work on these issues has already been submitted for publication).

Results of corticotropin (ACTH) level assays in the blood serum

Figure 1/Results – ACTH pg/ml depending on the group and the time of assay – *on next page*.

Results of ACTH pg/ml of the test made just before the parachute jump do not differ significantly ($p = 0.2490$) between the groups of jumpers. The results of this parameter on the next day after the jump differ highly significantly ($p = 0.0080$) between the groups of jumpers, but the difference concerns mainly the group after the first jump in relation to the group from the parachute sport section ($p = 0.0049$). Distributions of test results on a non-jumping day did not differ significantly ($p = 0.3455$) depending on the group.

Significant changes of the ACTH pg/ml results distributions were found in subsequent measurements in the group after the first jump ($p = 0.0388$) and among parachute instructors ($p = 0.0046$). No such difference was indicated in the group of the first season of jumps ($p = 0.2359$), in the group of parachutists ($p = 0.1561$) and in the section of sport parachuting ($p = 0.0743$).

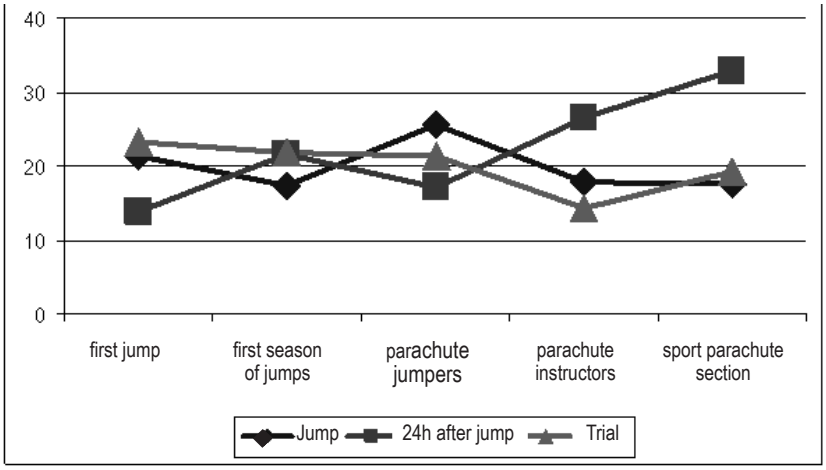

Figure 1. **ACTH pg/ml depending on the group and the time of measurement**

Statistically significant were:

- changes in ACTH level depending on the group in the assay performed 24 hours after the jump (the lowest value for the group performing the first jump and the highest for the sport parachuting section),
- changes in the levels of ACTH in the group performing their first jump (the lowest value 24 after the jump, and highest during the trial and on the day of the jump),
- changes in ACTH level in the group of parachute instructors (the lowest value during the trial and on the day of jump, and the highest 24 hours after the jump).

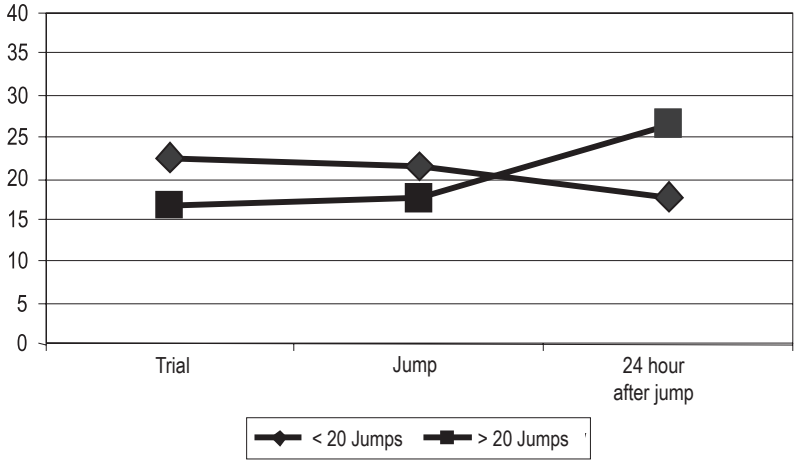

Figure 2. **ACTH pg/ml in particular measurements and depending on the number of jumps**

Significant differences were found in the results of ACTH pg/ml, depending on the number of jumps, before the jumping ($p = 0.0406$), on the next day ($p = 0.0170$) as

well as on a non-jumping day (p = 0.0326). Significant differences were also indicated in the results of ACTH pg / ml in particular assays, except that in the case of parsons having on account up to 20 jumps (p = 0.0156) significantly lower result was recorded the day after the jump, while among those who had made more than 20 jumps on the day after the jump the result was significantly higher (p = 0.0458).

Statistically significant were:

- changes in ACTH level depending on the number of jumps, in the assay on the day of jump (lower value for the group>20 jumps, and higher for the group <20 jumps),
- changes in ACTH level depending on the number of jumps, during the trial (lower values for the group>20 jumps, and higher for the group<20 jumps),
- changes in ACTH level depending on the number of jumps, in the assay 24 after the jump (lower value for the group <20 jumps, and higher for the group> 20 jumps),
- changes in level of ACTH in the group <20 jumps (the lowest value 24 hours after the jump and highest during the trial and on the day of jump),
- changes in level of ACTH in the group>20 jumps (the lowest value during the trial and on the day of jump, and the highest 24 hours after the jump).

Statistical conclusions

Relationship between the experience in performing parachute jumping as well as the number of jumps performed and the values of ACTH in particular assays was confirmed.

In the group of persons less experienced in performing jumps, the highest values of ACTH were observed during the trial and on the day of jump, and the lowest – 24 hours after the jump. An inverse relationship was found in the group of persons with more experience in performing jumps, they presented the highest values of ACTH 24 hours after the jump, and the lowest on the day of jump and during the trial.

At the same time in the measurement carried out 24 hours after the jump, an increase in the value of ACTH was indicated depending on the group, from the lowest value in the least experienced jumpers to the highest in the group with the greatest experience.

The results of cortisol level assays in the blood serum

Figure 3/Results – Cortisol ug/dL, depending on the group and the time of assay – *on next page*.

The results of measurements of cortisol ug/dL during the study just before parachute jumping did not differ significantly (p = 0.2639) between the groups of parachutists. The results of the parameter the next day after the jump differ highly significantly (p = 0.0052) between the groups of jumpers, and the difference concerns mainly the group after their first jump (p = 0.0088) and the group in the first season of jumping (p = 0.0391) compared to the group of the sport parachute section. Distributions of

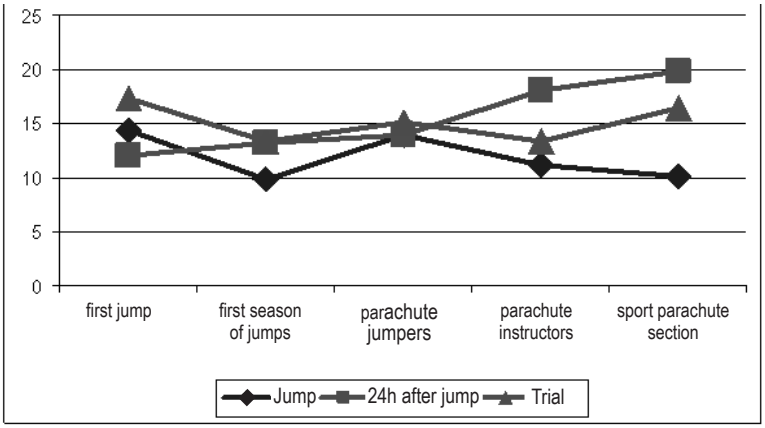

Figure 3. **Cortisol ug/dL, depending on the group and the time of measurement**

test results on a non-jumping day did not differ significantly (p = 0.5475) depending on the group.

There were no significant changes found in the distribution of cortisol results ug/dL in subsequent measurements in the group after the first jump (p = 0.1738) and the group of parachutists (p = 0.8669). Such differences were indicated in the group being in the first season of jumps (p = 0.0040), among parachute instructors (p = 0.0094) and in the parachute sport section (p = 0.0408).

Statistically significant were:

– changes in cortisol level, depending on the group, in the measurement 24 hours after the jump (the lowest value in the group performing the first jump, and during the first season, and the highest in a sport parachute section),
– changes in cortisol level in the group being in the first season of jumps (the lowest value on the day of jump and the highest during the trial and 24 hours after the jump),
– changes in cortisol level in the group of parachute instructors (the lowest value on the day of jump, higher during a trial and the highest 24 hours after the jump)
– changes in cortisol level in the sport parachute section – (the lowest value on the day of jump, higher during the trial and the highest 24 hours after the jump).

Figure 4/Results – Cortisol ug/dl in particular assays, depending on the number of jumps – *on next page*.

No significant difference in the distribution of cortisol level ug/dL were found, depending on the number of jumps before the jump (p = 0.5424) and on a non-jumping day (p = 0.3481), while 24 hours after the jump significant difference was indicated (p = 0.0017). There were also significant differences in cortisol ug/dl results found in the subsequent assays, but in the case of persons who had performed up to 20 jumps the differences were significant (p = 0.0402), while among those having performed more than 20 jumps were highly significant (p = 0.0014).

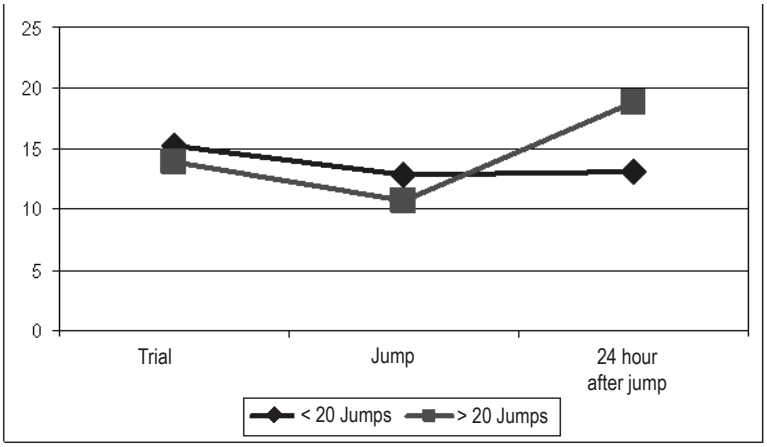

Figure 4. **Cortisol ug/dl in particular measurements and depending on the number of jumps**

Statistically significant were:

- changes in cortisol level depending on the number of jumps in the assay 24 after the jump (lower values for the group <20 jumps, and higher for the group >20 jumps),
- changes in cortisol level in the group <20 jumps (the lowest values during the assay on the day of the jump and 24 after the jump, and the highest during the trial)
- changes in cortisol level in the group >20 jumps (the lowest values during the measurement on the day of the jump, higher during the trial, while the highest 24 after the jump).

Statistical conclusions

The relationship between experience in performing jumps as well as the number of jumps already performed and cortisol values in particular measurements was confirmed.

In the assay made 24 hours after the jump, an increase of cortisol depending on the group was indicated – from the lowest value in the least experienced jumpers to the highest in the group with the greatest experience.

In all examined groups the lowest cortisol values were observed on the day of jump. In the groups with more experience in performing parachute jumps, the highest cortisol values were observed in measurements performed 24 hours after the jump. In the groups with less experience in performing jumps, the highest cortisol values were observed in measurements performed 24 hours after the jump and during the trial.

Discussion of results

Determination of the level of adrenocorticotropic hormone (ACTH) and cortisol in the blood or saliva is an established method of assessing the hypothalamic-pituitary

-adrenal (HPA) axis stress response [4, 5]. However, the relationship between the hormonal HPA axis response and subjective psychological response to stress depends on the different dynamics of these systems. Although stress theories typically assume a significant correlation between psychological and endocrine responses to stress, previous studies have brought inconclusive results [6]. In literature, there are reports suggesting both positive [7-10] and negative [11, 12] relationship of the hormonal responses to the subjectively assessed tension related to the stressor acting. The explanation for the contradictory information may be the suggested in literature different psychological and physiological reactivity of the stress response mechanism. Correlations in psychoendocrine stress response can therefore result from the different time of response delays of particular mechanisms to the existing stimulus [6].

Analysis of the results of ACTH and cortisol levels among the soldiers, who took part in the study, indicates a significant mobilization of these hormones in response to activation of the stress factor which is parachute jump among the soldiers with more experience in jumping and greater number of jumps already performed. This is manifested in high levels of hormones tested in assays performed 24 hours after the jump. At the same time, in these groups of jumpers, the initial hormone levels and the levels measured on the day of the jump are relatively low, in case of ACTH lower than in the groups less experienced in parachuting and with lower number of jumps. This indicates high reactivity of the hormonal HPA axis among experienced parachutists with relatively low initial concentrations of these hormones and their large mobilization in response to stress. However, in the group with less experience in parachute jumping, a slight decrease in the level of ACTH observed in the measurements performed 24h after the jump and a small cortisol level fluctuations in particular assays indicate a low reactivity of mechanisms responsible for the hormonal stress response.

Perhaps the high reactivity of the hormonal HPA axis among experienced parachutists is a mechanism developed in response to the chronic repetitive stress stimuli. According to Schlotz et al. high level of cortisol in response to stress corresponds with a low level of anxiety and arousal.. They also have stated that depending on the different dynamics of the two mechanisms, the endocrine response occurs with a significant delay in relation to the psychological response [6]. These reports are consistent with the observations made in this study, where the high level of hormonal response of experienced jumpers observed 24 hours after the jump correlated with low levels of subjective feeling of anxiety on the day of jumping. At the same time, the observed in the beginning jumpers low results of hormonal response level in relation to the relatively high sense of anxiety are consistent with reports of Chatterton et al., who studied the hormonal and psychological reaction to the stress associated with the first parachute jump. They observed high rates of psychological response and increased activation of the sympathetic nervous system, as well as low rates of hormonal response in the morning hours on the day of the first jump in the lives of the examined persons [13].

Conclusions

1. Stress stimulus, which is a parachute jump, influences the levels of ACTH and cortisol in the blood serum.
2. Different characteristics of hormonal activity (ACTH and cortisol) in response to emotional stress were found, depending on the experience of the study group in parachuting, with high hormonal HPA axis reactivity in the experienced and its low reactivity the in the beginning parachutists.

References

1. Martin P. *Umysł, który szkodzi. Mózg, zachowanie, odporność i choroba*, wyd. 1. Poznań: Rebis Dom Wydawniczy; 2000.
2. Frączek A, Kofta M. *Frustracja i stres psychologiczny*. W: Tomaszewski T. red. *Psychologi*a. Warszawa: PWN; 1976. s. 628 - 678
3. Spielberger CD, Gorsuch RL, Lushene RE. *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press; 1970.
4. Kirschbaum C, Hellhammer DH. *Salivary cortisol in psychoneuroendocrine research: recent developments and applications*. Psychoneuroendocrino. 1994; 19: 313.
5. Stroud LR, Salovey P, Epel ES. *Sex differences in stress responses: social rejection versus achievement stress*. Biol. Psychiatry 2002; 52: 318.
6. Schlotz W, Kumsta R, Layes I, Entringer S, Jones A, Wu S. *Covariance between psychological and endocrine responses to pharmacological challenge and psychosocial stress: a question of timing*. Psychosom. Med. 2008; 70: 787.
7. Abelson JL, Liberzon I, Young EA, Khan S. *Cognitive modulation of the endocrine stress response to a pharmacological challenge in normal and panic disorder subjects*. Arch. Gen. Psychiatry 2005; 62: 668.
8. Al'Absi M, Bongard S, Buchanan T, Pincomb GA, Licinio J, Lovallo WR. *Cardiovascular and neuroendocrine adjustment to public speaking and mental arithmetic stressors*. Psychophysiol. 1997; 34: 266.
9. Alpers GW, Abelson JL, Wilhelm FH, Roth WT. *Salivary cortisol response during exposure treatment in driving phobics*. Psychozom. Med. 2003; 65: 679.
10. Oswald LM, Mathena JR, Wand GS. *Comparison of HPA axis hormonal responses to naloxone vs psychologically-induced stress*. Psychoneuroendocrino. 2004; 29: 371.
11. Buchanan TW, Al'Absi M, Lovallo WR. *Cortisol fluctuates with increases and decreases in negative affect*. Psychoneuroendocrino. 1999; 24: 227.
12. Cohen S, Hamrick N, Rodriguez MS, Feldman PJ, Rabin BS, Manuck SB. *The stability of and intercorrelations among cardiovascular, immune, endocrine, and psychological reactivity*. Ann. Behav. Med. 2000; 22: 171.
13. Chatterton RT Jr, Vogelsong KM, Lu YC, Hudgens GA. *Hormonal responses to psychological stress in men preparing for skydiving*. J. Clin. Endocrinol. Metab. 1997; 82: 8.

Address: Edward Kowalczyk
Department of Pharmacology and Toxicology
of Medical University in Łódź;
90-647 Łódź, Hallera Square 1

Translated by Katarzyna Cyranka, MA