EFFECT ON MENTAL STRESS ON INTERMEDIATE CARBOHYDRATE-AND LIPID-METABOLISM

S. SHARDA, S.N. GUPTA AND K.P. KHUTETA*

Department of Physiology and Biochemistry, J.L.N. Medical College, Ajmer

Summary: Changes in blood levels of Glucose, Pyruvic acid, Lactic acid, Glycogen, Free Fatty Acids and total Serum Cholesterol have been studied in normal healthy human adults under the effect of mental stresses of pre-examination tension and pre-operative apprehension. A highly significant rise in all the parameters was noted.

Key words: mental stress pre-examination tension pre-operative apprehension intermediate metabolism FFA

INTRODUCTION

Metabolic changes occuring in an organism during 'stress' have received considerable attention since its advent by Selye (15) in 1937. The effects of various grades of physical exercise specially on carbohydrate metabolism are well-documented, physical stress being simple to produce under controlled experimental conditions. The same, however, is not true of mental stress, which is a non-specific condition. Statistical data suggests a higher incidence of atherosclerosis in conditions of mental tensions, responsibilities and frustrations. Emotional stress also has been etiologically linked with the development of coronary heart diseases (22). Selye (16) describes a biphasic response of serum cholesterol and lipids during stress in man. Friedmann *et al.* (8) reported no rise in the level of blood pyruvic acid in persons under usual stress of office work or work in laboratory. However, the effects on intermediate carbohydrate metabolism in corelation with the changes on the concentration of lipids in blood are scarcely reported. In the present study, blood levels of glucose, glycogen, pyruvic acid, lactic acid, total serum cholesterol and free fatty acids are studied under the effect of mental stress in pre-examination tension and pre-operative apprehension.

MATERIAL AND METHODS

The effect of two types of emotional stimuli were studied.

(a) *Pre-examination tension*: Twentyfive normal healthy medical students of both sexes were selected. The control blood samples were taken during the midsemester session in fasting state. The test samples (fasting) were obtained during their university examinations.

(b) *Pre-operative apprehension*: Twentyfive subjects of both sexes admitted to the hospital for elective surgery were selected after careful screening to rule out any endocrinal,

*Present address : Department of Physiology and Biochemistry, S.M.S. Medical College, Jaipur.

metabolic or renal disorder. The control fasting blood samples were obtained two days after their hospitalization so as to allow for their adjustments to the hospital surroundings. The test sample was collected in the operation-theatre prior to the premedication of anaesthesia.

Each of the blood samples were analysed for blood glucose (11), blood glycogen (12), blood pyruvic acids (7), blood lactic acid (1), serum cholesterol (14), and plasma free fatty acids (FFA) (21).

RESULTS

The observations are tabulated below:

TABLE I: Effects of pre-examination tension.

Series	*Glucose mgs/100 ml*	*Glycogen mgs/100 ml*	*Pyruvic acid mgs/100 ml*	*Lactic acid mgs/100 ml*	*Total cholesterol mgs/100 ml*	*FFA mEq/L*
Control	74.36 ± 4.75	5.99 ± 1.28	1.17 ± 0.27	8.81 ± 1.60	173.40 ± 21.40	0.51 ± 0.19
Test	90.64 ± 6.65	7.62 ± 1.55	1.58 ± 0.28	12.10 ± 1.50	213.80 ± 26.10	0.85 ± 0.25
Difference	+16.28	+ 1.62	+0.41	+ 3.28	+ 40.36	+ 0.33
% Increase	17.80	26.60	31.46	26.60	23.30	64.70
Significance	P<.01	P<.01	P<.01	P<.01	P<0.1	P<.01

TABLE II: Effects of pre-operative apprehension.

Series	*Glucose mgs/100 ml*	*Glycogen mgs/100 ml*	*Pyruvic acid mgs/100 ml*	*Lactic acid mgs/100 ml*	*Total cholesterol mgs/100 ml*	*FFA mEq/L*
Control	68.78 ± 3.72	6.00 ± 1.50	1.00 ± 0.23	9.20 ± 1.92	178.92 ± 28.22	0.44 ± 0.11
Test	86.84 ± 5.84	7.77 ± 0.72	1.32 ± 0.27	12.77 ± 2.80	223.64 ± 27.40	1.14 ± 0.30
Difference	+17.76	+ 1.68	+ 0.32	+ 3.57	+ 44.76	+ 0.70
% Increase	20.01	28.30	32.00	40.20	24.90	159.09
Significance	P<.01	P<.01	P<.01	P<.01	P<.01	P<.01

The effect of emotional stress in both the forms: pre-examination tension and pre-operative apprehension, showed a significant increase in the concentrations of glucose, glycogen, pyruvic acid, lactic acid, total cholesterol and FFA in blood.

DISCUSSION

The 'stress' enhances the activity of the cortico-hypothalamico-hypophysio-sympatho-adrenocortical axis, resulting into the increased liberation of catecholamines and corticoids in circulation. This subsequently causes increased hepatic glycogenolysis and gluconeogenesis, thus increasing the concentration of glucose in peripheral circulation (13). It is known that the blood-glycogen is localised in granulocytes (19). Exercise and various emotional stresses have

been shown to cause the polymorphonuclear leucocytosis. Dobreff and Tomoff (4) also observed similar type of leucocytosis of emotional origin in subjects before undergoing operative surgery and in students taking an examination. Ellis has reported (6) an increased concentration of the enzyme glucose-6-phosphatase in blood during stressful stimulation. This may help in the increased biosynthesis of glycogen by the granulocytes. Thus, the increased concentration of glycogen in peripheral blood can possibly be attributed to the increased concentration of glucose-6-phosphatase and the polymorphonuclear leucocytosis under the effect of mental stress.

The hyperlactacidaemia and the hyperpyruvic acidaemia can be taken as the essential metabolic corollaries of various types of stressors including exercise and mental stress. This can be possibly due to increased formation and liberation of epinephrine which enhances the activation of the enzyme phosphorylase (10) resulting into an overall increase in the aerobic as well as anaerobic carbohydrate metabolism, thus raising the blood-levels of both lactic acid and pyruvic acid. One of the causative factors for the raised concentrations of the two acids in blood may be the increased secretion of adreno-corticoids during emotional stress. Epinephrine induces liberation of gluco-corticoids during the stresses which affect carbohydrate metabolism leading to increased concentration of the intermediary metabolites, lactic acid and pyruvic acid in blood.

Pre-examination tension and pre-operative apprehension, both caused a highly significant rise in the concentration of serum total cholesterol in the present study. There are reports (2, 9) stating similar rise in accountants during the audit session. Dreyfuss and Czaczkes (5) found the blood cholesterol in medical students higher during the examinations than it was two days after the examination This can be attributed to the increased mobilization of cholesterol as it is a potential source for the adrenal steroid hormones. These cortico-steroids are required in large quantities in order to cope with the situation of tension, which may be under the effect of the released lipid mobilising hormone (LM) under stress. Zarafonetis and his associates (23) have reported the release of LM during surgical stress in human beings.

Plasma free fatty acids (FFA), is the major transport form of fatty acids which are carried from adipose tissue depots to tissues for oxidative purposes. Both pre-examination tension and pre-operative apprehension caused a significant rise in plasma FFA level. Taggart *et al.* (20) have reported rise in the concentration of plasma FFA in the racing drivers. Also Somerville *et al.* (18) reported rise in FFA in speakers immediately before and also after addressing a medical meeting. Probably, the increase of catecholamines which results as a normal emergency response to stress causes mobilization of fat leading to an increase in FFA concentration in peripheral blood. During stress, there is activation of ACTH and this further causes release of cortico-steroids which potentiate the action of epinephrine (3). As the uptake of FFA by the tissues from the plasma is not much altered under emotional stress, the increased influx causes the high levels of FFA in circulation. As postulated by Siperstein (17), it is likely that glucose in addition to serving the vital functions of providing the substrate for the operation of Kreb's cycle, acts as a generating system for the reduced pyridine nucleotides. It is through these co-enzymes that stress-induced glycolysis is able to exert its regulatory influence on lipid metabolism.

ACKNOWLEDGEMENT

Authors thankfully acknowledge the facilities provided by the Principal and Controller, Associated Group of Hospitals, Ajmer, to carry out the study and report.

REFERENCES

1. Barker, S.B. and W.H. Summerson. The colorimetric determination of lactic acid in biological material. *J. Biol. Chem.*, **138** : 535-554, 1941.
2. Bogdonoff, M.D., E.H. Estes, W.R. Harlan, D.L. Trout and N. Kirshner. Metabolic and Cardiovascular changes during a state of acute central nervous arousal. *J. Clin. Endocrinol.*, **20** : 1333-40, 1960.
3. Carlson, L.A., L. Levi and L. Oro. Plasma lipids and urinary excretion of catecholamines in man during experimentally induced emotional stress and their modification by Nicotinic acid. *J. Clin. Invest.*, **47** : 1795-99, 1968.
4. Dobreff, M. and W.L. Tomoff. *Ztschr. f.d. ges. exper. med.*, **84** : 695-701, 1932. sited from "Emotions and bodily changes". Flanders Dunbar, 4th edition, Columbia University Press.
5. Dreyfuss, F. and J.W. Czaczkes. Blood cholesterol and uric acid of healthy medical students under the stress of an examination. *A.M.A. Arch. Int. Med.*, **103** : 708-714, 1959.
6. Ellis, S. The Metabolic effects of Epinephrine and related amines. *Pharmacol. Rev.*, **8** : 485-542, 1956.
7. Friedmann, T.E. and G.E. Haugen. Determination of keto-acids in blood and urine. *J. Biol. Chem.*, **147** : 415-442, 1943.
8. Friedmann, T.E., G.E. Haugen and T.C. Kmieciak. The level of pyruvic and lactic acids and the lactic/pyruvic ratio in the blood of human subjects : The effects of food, light muscular activity and anoxia at high altitudes. *J. Biol. Chem.*, **157** : 673-689, 1945.
9. Friedmann, M., R.H. Rosenman and V. Carrol. Changes in Serum Cholesterol and blood-clotting time in men subjected to cyclic variation of occupational stress. *Circulation*, **17** : 852-861, 1958.
10. Greene, N.M. Effect of epinephrine on lactate, pyruvate and excess lactate production in normal human subjects *J. Lab. and Clin. Med.*, **58** : 682-685, 1961.
11. Hjelm, M. Enzymatic determination of hexose in blood and urine. *Scand. J. clin. Lab. Invest.* (*Suppl*), **192** : 85-98, 1966.
12. Kemp, A. and V.H. Kits. Colorimetric micromethod for determination of glycogen in tissues. *Biochem. J.*, **56** : 646-648, 1954.
13. Landau, B.R. Adrenal steroids and carbohydrate metabolism. *Vitamins Hormones*, **21** : 135-214, 1963.
14. Leffler, H.H. and H.C. McDougald. *Am. J. Clin. Pathol.*, **39** : 311-315, 1963. Cited from Atlas of Clinical Chemistry.
15. Selye, H. Quoted by Selye, H. "Stress", Montreal acta Inc. p.2, 1950.
16. Selye, H. The Physiology and Pathology of exposure to stress. *Montreal acta Inc.*, p. 278, 1950.
17. Siperstein, M.D. Inter-relationship of glucose and lipid metabolism. *Am. J. Med.*, **26** : 685-702, 1959.
18. Somerville, W., P. Taggart and M. Carruthers. Addressing a medical meeting : Effect on heart-rate, Electrocardiogram, plasma catecholamines, FFA and triglycerides. *Br. Heart J.*, **33** : 608-613, 1971.
19. Spector, W. Cited from 'Handbook of Biological data', W.B. Saunders, Philadelphia and London, 1956. p. 52.
20. Taggart, P. and M. Carruthers. Hyperlipidaemia induced by the stress of racing driving. *Lancet*, **1** : 854-858, 1971.
21. Trout, D.L., E.H. Estes Jr., S.J. Friedberg. Titration of FFA of plasma : a study of current methods and a new modification. *J. Lipid Research*, **1** : 99-103, 1960.
22. Wolf, S., W.R. McCabe, J. Yamahoto, C.A. Adset and W.W. Schottstaedt. Changes in serum lipids in relation to emotional stress during rigid control of diet and exercise. *Circulation*, **26** : 379-387, 1962.
23. Zarafonetis, C.J.D., J. Seifter, D. Baeder and J.P. Kalas. Lipid mobilisation as a consequence of surgical stress. *Am. J. Med. Sc.*, **237** : 418-423, 1959.