Study of the Metabolic Status by Complex Indirect Calorimetry and Bioimpedometry

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Evaluation of the metabolic status by combined use of indirect calorimetry and body composition by the parameters of protein and fat utilization is proposed.

Key Words: *metabolic status; protein and fat utilization coefficients*

The balance between the consumption of nutrients and their free energy and the actual requirements of the organism determines optimal nutrition of humans in health and disease. This philosophy is realized as a stable balance of the rate of macronutrient and energy consumption and the summary rates of glucose, fatty acid, and amino acid oxidation in the body. This principle is based on the fact that amino acid oxidation rate determines the protein requirements of the organism [5,6,10,11]. This assumption can be fully extrapolated to glucose and fatty acid oxidation rates.

Study of oxidative metabolism by endogenous rates of glucose, amino acid, and fatty acid oxidation by indirect calorimetry at rest and during exercise provides a tentative evaluation of metabolic disorders in maladaptation and development of nutrition-dependent disease [7-9]. However, the oxidation rates of the main macronutrients should be converted to the units of body weight and its constituents, primarily fatty and lean weights, which fact is virtually neglected at present. These specific values can provide the most complete information about the severity of disorders in energy, protein, and fatty metabolism and serve the base for the development of individual therapeutic diets.

We compared the metabolic status of cardiovascular patients and diabetics (type 2 diabetes mellitus; DM).

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MATERIALS AND METHODS

The study was carried out in 154 cardiovascular patients (21 male and 133 female ones) aged 20-80 years (mean age 55.7±0.9 years) with body weight index (BWI) 35.9±0.5 kg/m^2 with essential hypertension and coronary disease and 80 patients with type 2 DM combined with obesity (3 men and 77 women) aged 31-69 years (mean age 55.8±0.9 years) with BWI of 38.9±0.7 kg/m^2, hospitalized at Institute of Nutrition.

Indirect calorimetry at rest was carried out on a Vmax Spectrum stationary metabolograph Vmax Spectrum (SensorMedics) using Vmax-Spectra Software.12.1; concentrations of O_2 and CO_2 in inhaled and exhaled air flows were recorded (in configuration with dilution helmet). The urea nitrogen excretion rate was evaluated by the standard clinical biochemical method with consideration for 24-h diuresis.

Body composition characteristics (fat weight, lean weight, active cell mass, water weight) were measured by bioimpedometry by the standard method using ABC01-036 software on an ABC-01 analyzer (MEDASS). For more precise evaluation, correction coefficients with consideration for sex, age, and nosological entity were introduced in the ABC01-036 software (coefficients were estimated previously by comparing body composition characteristics evaluated by bioimpedometry and X-ray densitometry (Prodigy GE LUNAR Corporation) [1]).

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The rate of energy consumption at rest was calculated by modified Weyer—Ferrannini equation [3]:

$$E=3.78\times Vo_2+1.16\times Vco_2-2.98\times N,$$

where E is energy consumption rate at rest (kcal/day), Vo_2 is oxygen consumption rate (liter/day), Vco_2 is CO_2 production rate (liter/day), and N is urinary urea nitrogen excretion rate (g/day).

Metabologram calculation was carried out using modified Ferrannini's equation [3] with intermediate evaluation of non-protein energy consumption (NE) and non-protein respiratory coefficient (NRC):

$$NE=3.78\times(Vo_2-6.04\ N)+ 1.16\times(Vco_2-4.89\times N)-2.98\times N,$$
$$NRC=(Vco_2-4.89\times N)/(Vo_2-6.04\times N),$$

where $6.04\times N$ and $4.89\times N$ are protein quotas for O_2 consumption and CO_2 production.

The proportions of oxidized carbohydrates and lipids were calculated by the formulas:

carbohydrate oxidation %=(NTC-0.7)×100/0.3,
lipid oxidation %=100-carbohydrate oxidation %.

Macronutrient oxidation rates were calculated by formulas:

$$POR=E-NE,$$
$$LOR=\text{lipid oxidation }\%\times NE/100\%,$$
$$COR=\text{carbohydrate oxidation }\%\times NE/100\%,$$

where POR is protein oxidation rate (kcal/day), LOR is lipid oxidation rate (kcal/day), and COR is carbohydrate oxidation rate (kcal/day). After dividing by caloric coefficients (4.1, 9.3, and 4.0 kcal/g for proteins, lipids, and carbohydrates, respectively) the results were expressed in g/day.

Due to specially derived accessory coefficients, evaluation of the metabolic status better individualized:

$$SR=E/(\text{total body weight(kg)}\times 24\ \text{h}),$$
$$FUC=LOR(\text{g/day})\times 10\%/\text{fat weight (g)},$$
$$PUC=POR(\text{g/day})\times 10\%/\text{lean weight (g)},$$

where SR is energy metabolism specific rate at rest (kcal/(kg×h), FUC is fat utilization coefficient (%:day), and PUC is protein utilization coefficient (%:day).

The results were processed by standard parametric methods.

RESULTS

Monitoring of the metabolic status of cardiovascular patients and diabetics with obesity showed characteristic significant differences between energy consumption values and macronutrient oxidation rates at rest in comparison with the normal level and between the groups (Table 1).

Energy consumption at rest in cardiovascular patients and diabetics (1448 and 1637 kcal/day, respectively) were higher than in health, primarily because of high content of active cell mass (29.4±0.5 and 30.8±0.45 kg, respectively). On the other hand, the specific rates of energy metabolism at rest (values leveling the anthropometric differences) in the studied patient populations were 32 and 27% lower, respectively, than normally ($p<0.01$). It seems that low level of energy metabolism, noted in cardiovascular patients and diabetics with type 2 disease can be one of the causes of energy imbalance leading to excessive deposition of fat, development and progress of obesity and the metabolic disorders and risk factors associated with it.

The proportion of substrates, used by the body for oxidative metabolism, is essential for main-

TABLE 1. Metabolograms of Cardiovascular Patients and Diabetics with Type 2 Disease and Obesity at Rest

Parameter	Cardiovascular patients (n=154)		Type 2 DM (n=80)	
	normal values	patients	normal values	patients
E, kcal/day	1249±11.5	1448±23.3**	1212.0±9.8	1637.00±31.6**
SE, kcal/(kg×h)	0.931±0.003	0.636±0.007**	0.939±0.004	0.686±0.012**
POR, g/day	45.7±0.42	66.2±2.45**	44.4±0.36	51.9±3.19*
LOR, g/day	66.2±0.61	54.6±2.96**	64.3±0.52	67.9±4.2
COR, g/day	111±1.03	170±6.2**	108.00±0.88	194.0±9.3**
PUC, %:day	8.37±0.03	12.8±0.51**	8.5±0.06	9.6±0.6
FUC, %:day	41.8±0.47	13.0±0.71**	40.3±0.4	15.80±0.94**

Note. *$p<0.05$, **$p<0.01$ compared to the normal level. Normal values were calculated by the standard body length/weight and weight/energy equations.

taining normal body weight and energy balance at rest. Normally the percentage of oxidized fats predominates (58%), that of oxidized carbohydrates being 42%. Our study showed that carbohydrates were the main oxidation substrate at rest for cardiovascular patients (42% oxidized fats and 58% oxidized carbohydrates) and for diabetics (45 and 55%, respectively). Negative trends, manifesting by the disproportion of oxidized substrates, were augmented by disorders in lipid oxidation rates, particularly in cardiovascular patients. Lipid oxidation rate in this group was 54.6±2.96 g/day, which was significantly lower ($p<0.01$) than normally, while in the diabetics no statistically significant differences were detected. This fact (more rapid oxidation and higher proportion of oxidized fat in diabetics in comparison with cardiovascular patients) can presumably be attributed to specific features of the pathogenetic mechanisms of metabolic disorders, primarily the development of insulin resistance, when free fatty acids serve as the main substrate for energy requirements.

The diagnostic informative value of analyzed parameters (lipid oxidation rates) increased significantly due to FUC evaluation: this coefficient was significantly reduced in cardiovascular patients and diabetics (by 28.8 and 24.5%:day, respectively; $p<0.01$) in comparison with normal subjects. It seems that lipid oxidation rates in cardiovascular patients and diabetics are obviously insufficient for adequate utilization of fat and maintenance of normal body weight. Hence, in order to evaluate the metabolic status and plan individual diets, not only the actual rates of lipid oxidation should be measured, but their adequacy to body composition parameters should also be estimated for more effective correction of body weight and metabolic disorders, inevitably linked with fat excess.

Statistically significant differences in protein oxidation and utilization rates were also detected in the patients. Protein oxidation rates were significantly higher than normally in cardiovascular patients (by 20.5 g/day; $p<0.01$) and in diabetics (by 7.5 g/day; $p<0.05$). However, conversion of the analyzed values to the lean weight (PUC) indicated high intensity of oxidative catabolism of protein ($p<0.01$) only in cardiovascular patients, while in the diabetics this parameter virtually did not differ from the normal level. These results indicate that the therapeutic rations for cardiovascular patients should be corrected by the protein component for leveling the probable untoward consequences of excessive protein catabolism.

On the whole, the results indicate the desirability of differentiated approach to development and optimization of diets with consideration for the detected metabolic characteristics in the two nosological groups.

These results suggest analysis of patients' metabolograms not only in order to detect the risk groups and precisely evaluate the metabolic picture of the pathogenesis of nutrition-dependent diseases, but also in order to develop individual diets. Body composition and results of evaluation of the meta-

TABLE 2. Individual Metabolograms of Patients with Essential Hypertension at Rest

Parameter	Patient 1		Patient 2	
	individual norm	result	individual norm	result
Body weight, kg	58.1	75.7	50	76.9
Fat weight, kg	9.2-16.8	30.7	8.8-15.5	34.7
Lean weight, kg	35-58	45	30-48	42.2
E, kcal/day	1218	1226	1149	1241
SE, kcal(kg×h)	0.873	0.675	0.957	0.672
DC	0.825	0.89	0.825	0.84
Lipid oxidation %	58	32	58	49
Carbohydrate oxidation %	42	67	42	51
POR, g/day	44.5	45.0	41.7	60.5
LOR, g/day	64.5	36.3	60.4	45.5
COR, g/day	109	176	102	142
PUC, %:day	7.7	10.0	8.69	14.3
FUC, %:day	38.4	11.8	39.0	13.1

Note. Normal individual values were calculated from the "ideal weight" and body length and weight values.

bolic status of two patients with the same disease (essential hypertension) with about the same body weight are presented. These data indicate differences in the macronutrients' oxidation rates and substrate utilization coefficients (Table 2).

Low levels of specific energy turn-over (SE) were detected in both patients with essential hypertension. This fact necessitates reduction of energy value of diets to 1220 and 1240 kcal/day for patients 1 and 2, respectively. The detected individual structure of energy consumption (low rate of lipid oxidation in patient 1: 36.3 g/day *vs.* 64.5 g/day, and high rate of protein oxidation in patient 2: 60.5 g/day *vs.* 41.7 g/day) necessitate individual correction of therapeutic rations, standard for this patient population, by the macronutrient composition. It is obvious that the content of proteins, lipids, and carbohydrates for patient 1 with consideration for the metabolic status should constitute 15, 27, and 58% of ration's energy value, while for patient 2 these values should be 20, 34, and 46%, respectively.

Hence, the results obtained by modern nutrimetabolomic methods indicate specific metabolic status, characteristic of different nosological entities. Moreover, these data evidence metabolic heterogeneity of patients within the same group, this necessitating the use of the above-described clinical approach to individual dietological correction of metabolic disorders and improving the efficiency of prevention and treatment of nutrition-dependent diseases.

It is also obvious that the criteria for correction of therapeutic rations in diabetics with type 2 disease and cardiovascular patients should be based on analysis of patients' metabolograms, body composition characteristics, and data of standard biochemical and hormone tests [2,4,8]. Final correction of therapeutic rations should be based on metabolograms at rest and metabolograms recorded under other physiological conditions, including exercise and test meals. Highly informative parameters can be obtained with consideration for all the basic factors. These parameters are essential for understanding the metabolic mechanisms in the pathogenesis of nutrition-dependent diseases and for adequate nutritive support before and after intervention, in cancer patients during chemotherapy, in prescription of foodstuffs for enteral nutrition, and for optimization of rations in athletic and labor medicine.

The method for formation and evaluation of metabologram by a complex including indirect calorimetry and bioimpedometry is an obligatory initial component in the diagnosis of nutrition-dependent diseases and individual planning of diets. On the other hand, it is obvious that multilevel nutrimetabolomic studies are essential for prenosological evaluation of the health status, evaluation of the risk of nutrition-dependent diseases, and for highly individual dietetic therapy.

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