University of Jordan
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Gastrointestinal Physiology, Pt IV.

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ENERGETICS, METABOLIC RATE, DIETARY BALANCE and REGULATION OF FOOD INTAKE:

After the chemical transformation of food into smaller food stuffs and their absorption, food stuff will undergo many processes by the cells of human body to produce energy for their activities.

The energy produced by these reactions is stored in highly energetic phosphate bonds in a compound known as ATP. The formed ATP then is used for body works which could be as external or internal works. These include:

Chemical works: building of cellular components, secretions, etc.
Mechanical works: muscle contractions, heart pumping, etc.
Electrical works: after nerve conduction by maintaining a concentration gradient for K+ and Na+ across membrane by the activity of Na+/K+ pumps and other pumps).

Another highly energetic compound that can transfer energy (when needed) to ATP is phosphocreatine. This occurs by the following reaction:

Phosphocreatine + ADP ⇆ ATP + Creatine

The abundance of creatine permits more storage of energy in this high energetic compound which can energize the ADP when there is a decrease in ATP concentration.

ATP formation by chemical reactions in the body:

The energy produced by chemical reactions that need oxygen is known as aerobic energy. Most of energy produced in our body is in the form of aerobic energy.

Some ATP molecules can be produced by anaerobic reactions such as glycolysis (break down of glucose into pyruvic acid). This is a form of **anaerobic energy**. This anaerobic energy can be generated when there is

lack of oxygen such as in hypoxia or when there is a high activity (such as in muscle) and inadequate supply of oxygen. This later condition will result in accumulation of lactic acid in the muscle.

The **aerobic energy** is produced by enzymatic reactions (chemical burning of food stuff by using O_2 to produce energy). These reactions are very well controlled in our body. The final products of complete break down of food stuff will result in the formation of H_2O and CO_2.

In the case of chemical burning of glucose, we have the following reaction: $C_6 H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$

From this reaction we can calculate "Respiratory Quotient" (RQ) (CO2 produced/O2 consumed) when glucose is used as a source of energy

In this reaction (RQ) = CO_2/O_2 = 1.0 in the case of glucose break down.

When **fat** is used as source of energy, RQ = **0.7**.

When **protein** is used, RQ = **0.8**.

The RQ when **mixed** food stuff is used = **0.82**.

From the respiratory exchange ratio by the lung over a period of time we can estimate the respiratory quotient for all body to indicate the main type of food stuffs used for metabolism in the body.

METABOLIC RATE:

Metabolism refers to all chemical reactions in our body.

The energy produced and consumed in chemical reactions and body works will finally generate **heat** (appears by the interconversion between the forms of energy). The rate of heat production is known as the *metabolic rate*. The heat produced can be measured to reflect the metabolic activities in the human body.

The measurement of metabolic rate has clinical importance mainly when is measured under **basal conditions**. The metabolic rate under these conditions is known as **basal metabolic rate** and refers to the minimal energy expenditure by a body to exist.

Basal conditions:

The person to whom we intend to measure the metabolic rate is **not in sleep** and the following basal conditions must be met:

1. No eaten food for at least 12 hours.
2. measurement after a night of restful sleep.
3. No exercise and physical activities in at least one hour prior to and during the test.
4. elimination of all factors that may cause excitement.
5. comfortable temperature during measurement.

Measurements of metabolic rate:

The Calorie is the used unit for measuring heat produced by the body. Calorie spelled with C capital to mean 1kilocarie (1000 calories).

Direct calorimetry:

Measuring the heat produced with direct methods by calorimeter (an insulated chamber constructed with a constant rate of water flow (in and out) to measure the heat taken by the flow of water).

Indirect calorimetry:

Closed circuit method:

More than 95% of the energy is produced by oxygen consuming chemical reactions. The rate of heat production can be calculated from the amount of oxygen consumed. The heat produced by our body is about 4.825 Calories per one liter of oxygen consumption (*energy equivalent of oxygen*). By using the spirometer as metabolator by equipping it (filling it with pure oxygen and adding in the way of expired air a substance to adsorb the CO_2 produced) we can measure O2 consumption.

The heat produced is calculated as **the amount of heat/m^2 surface body/hour**.

There is an example for calculation of metabolic rate:

If we measure in 5 minutes:
oxygen consumption of 1000ml of pure oxygen/5minutes.
Per hour the Oxygen consumed would be:

1000ml X 12 = 12 Liters/hour.

For that amount of oxygen consumed
the energy produced is:
12 liters/hour X 4.825 Cal./liter = 57 Cal./hour.

We can have the surface area of the body from tables designed to have the surface area by knowing the weight and height of a person.

If we have it as $1.7m^2$.

Then the amount of heat produced is:
57 Cal. $hour^{-1}$/1.7 m^2 = 34 Cal. $hour^{-1}/m^2$.

The basal metabolic rate can be related to the ideal basal metabolic rate and expressed as a % increase or decrease from the ideal basal metabolic rate for that person.

Opened Circuit method

Other indirect methods are used for measuring metabolic rate during certain activities is by using **opened circuit methods**:

In these methods a bag is used for collection of expired air during the physical activity.

By knowing the concentration of oxygen in the atmosphere and in collected air. We can know how much oxygen was consumed and then we can calculate oxygen consumption and the metabolic rate in the same way as above.

Factors affecting metabolic rate:

Exercise: increases metabolic rate. This increase is well related with the strength of the exercise.

Daily activities: the metabolic rate depends on the daily activities. For a lie in bed all day the metabolic rate is about 1600 Cal/day. Eating process increases the rate by 200 Cal. Etc.

Age: the metabolic rate calculated for the surface are of the body decreases with age. It is higher in children and less in old people.

Sleep: decreases the metabolic rate.

Climate: the metabolic rate for people living in tropical regions is less.

Fever: during infection there is an increase in metabolic rate.

Malnutrition: Decreases metabolic rate.

Effect of hormones:

Thyroid hormones: increase the metabolic rate.

Male sex hormones increases the basal metabolic rate by 10-15%.

Growth hormones: Increases metabolic rate by15-20%.

Effect of sympathetic stimulation: increases metabolic rate.