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Glossary of Terms Used in Energy Assessment

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All living things require energy to sustain life. If a plant, that energy comes from the sun. If an animal, the energy must be provided by the food that is consumed. Warm-blooded animals are kept warm by their metabolisms. All the reactions that comprise intermediary metabolism release heat as a byproduct. Some reactions are exogonic; that is, they release more heat than they consume. Others are endogonic; they consume more energy than they release. None of the reactions in a living system are 100% efficient. The reaction produces a product(s) plus heat. This is the heat that sustains the body temperature and yet also escapes from the body via radiation or evaporation (insensible water loss and sweating) from the body surface. If a body is neither gaining nor losing weight, the energy released as heat is equal to that needed by the body to sustain its metabolism. Thus, the heat that is produced is equal to the total food energy (corrected for digestive loss and internal energy conversion to mechanical, chemical, and electrical energy) that must be provided on a daily basis to sustain the body. Altogether, the living system is a heat-generating system. That heat can be measured directly using a calorimeter or indirectly by measuring the oxygen consumed and the carbon dioxide produced. Using equations that relate heat production to the gas exchange (CO_2 and O_2), the energy used by the body can be calculated.

The measurement of energy need and energy production has been the subject of nutritional investigation since the time of Lavoisier. A number of terms have evolved that refer to discrete portions of the energy equation. These are listed in Table 34.1 along with other terms relevant to energy balance in man and other species.

The standardization of energy terms has been published by the National Academy of Sciences.[1] Nutrition scientists (as well as other scientists interested in energy metabolism) are encouraged to use these terms.

TABLE 34.1

Terms of Reference in Energy Metabolism

Anabolism: the totality of reactions that account for the synthesis of the body's macromolecules; heat is a byproduct of these reactions.

Android obesity: a form of obesity where fat distribution is mainly in the shoulders and abdomen; sometimes referred to as the "apple" shape.

Anthropometry: Measurements of body features, i.e., weight, height, etc.

Apparent digested energy (DE): energy of the consumed food (IE) less the energy of the feces (FE); DE = IE – FE.

Archimedes principle: an object's volume when submerged in water equals the volume of the water it displaces. If the mass and volume are known, the density can be calculated. This principle is used to determine body fatness.

Balance: When energy intake (EI) equals energy expenditure (EE), energy balance is zero. When energy intake exceeds expenditure, balance is positive and weight is gained. When intake is less than expenditure, balance is negative and weight is lost. (EI = EE; balance = 0)

Basal metabolic rate (BMR): the energy required to sustain life; measured in a resting animal in a thermoneutral environment (neither sweating nor shivering), at sexual repose, and in the postabsorptive (but not starving) state. Expressed as heat units/hour/unit body surface or per unit body weight ($Kg^{0.75}$). A less stringent measurement of this basal energy requirement is the resting metabolic rate (RMR). RMR is measured under clinical conditions to provide an approximation of the BMR and provide a basis for diet recommendations.

Body cell mass: the metabolically active, energy-requiring mass of the body.

Body density: mass (weight) per unit volume.

Calorie: a unit of heat energy; a calorie is defined as the amount of heat required to raise the temperature of one gram of water one degree Celsius; this is the physicist's unit. The nutritionist's unit is the calorie or kilocalorie (abbreviated, kcal), and refers to the heat needed to raise the temperature of one kilogram of water rather than one gram of water. The term kilojoule is the preferred term for expressing the energy need for living systems because it accounts for not only heat energy but also other forms of energy (mechanical, electrical, etc.) that living systems use. The kcal can be converted to the kilojoule by multiplying kcal × 4.184.

Calorimetry: the measurement of heat production by the body. This measurement can be either direct (using a whole body calorimeter) or indirect (using measurements of oxygen consumed and carbon dioxide produced).

Catabolism: the totality of those reactions that reduce macromolecules to usable metabolites, CO_2, and water. Heat is a byproduct of these reactions.

Digestive energy (DE): the energy of food after the energy losses of digestion are subtracted. Similar to apparent ingestive energy (see above).

Gaseous products of digestion (GE): the energy of combustible gases produced in the digestive tract incident to fermentation of food by microorganisms. In ruminants, that can account for a substantial energy lost from the system. In nonruminents this loss is relatively minor.

Gynoid obesity: excess body fat deposited mainly on the hips and thighs; sometimes referred to as the "pear" form of obesity.

Heat of activity (HjE): the heat produced through muscular activity; an active person can have a very large percent of their energy need accounted for by HjE. A sedentary person can have the reverse. The energy need for different activities has been determined, and some of these are listed in Table 34.2. Sometimes TEA (total energy from activity) is used for this term.

Heat of digestion and absorption (HdE): the heat produced as a result of the action of the digestive enzymes, and the heat produced when the products of digestion are absorbed. Expressed in heat units (see DE above). Sometimes DIT (diet-induced thermogenesis) is used.

Heat of fermentation (HfE): the heat produced in the digestive tract as a result of microbial action. Expressed in heat units (see GE above).

Heat of product formation (HrE): the heat produced in association with metabolic processes of product formation from absorbed metabolites. In its simplest form, HrE is the heat produced by a biosynthetic pathway. Expressed as heat units.

Heat of thermal regulation (HcE): the additional heat needed to maintain body temperature when the environmental temperature falls below or rises above the zone of thermic neutrality. Expressed in heat units. Sometimes CIT (cold-induced thermogenesis) or BAT (brown fat thermogenesis) is used. It is thought that the heat generated upon cold exposure emanates primarily from the brown fat depots. There is some argument about this role of the brown fat.

Heat of waste formation and excretion (HwE): the additional heat production associated with the synthesis and excretion of waste products. For example, the synthesis and excretion of urea is energetically expensive in mammals and results in a measurable increase in total heat production. Expressed in heat units.

TABLE 34.1 *(Continued)*

Terms of Reference in Energy Metabolism

Heat increment (HiE): the increase in heat production following the consumption of food. Includes the heat lost through digestion and absorption and the heat of fermentation. Expressed as heat units. The heat increment is usually considered non-useful energy loss, but under special circumstance (cold environments) it helps to maintain the body temperature.

IBW: ideal body weight.

Indirect calorimetry: the calculation of energy production through the measurement of oxygen consumed. It is predicated on the relationship of the heat lost when substrates are oxidized to CO_2 and water. With this oxidation via the mitochondrial respiratory chain, some energy is trapped in the high-energy bond of ATP. The rest of the energy is released as heat. Because there is a relationship between oxygen used and the energy trapped plus energy released as heat, measuring the oxygen consumed is an indirect measure of heat production. Thus, at zero energy balance, heat production (oxygen consumed) can predict the energy need of the body at rest or when actively involved in a variety of tasks. There are several systems available for this measurement. The closed system uses a reservoir of gases, and the oxygen consumed is measured. The open system measures the carbon dioxide exhaled without measuring oxygen consumed.

Metabolizable energy (ME): the energy in food minus the energy lost through digestion and absorption, the energy of undigested residues (FE), and the energy lost through fermentation. ME = IE – (FE + UE + GE).

N-corrected metabolizable energy (MnE): ME adjusted for total nitrogen retained or lost from body tissue. MnE = ME – (k × TN). For birds or monogastric mammals, gaseous energy is usually not considered. The correction for mammals is generally k = 7.45 kcal/g/nitrogen retained in body tissue (TN). The factor 8.22 kcal/g TN is used for birds, representing the energy equivalent of uric acid/g nitrogen.

NPU: net protein use.

NDp cal %: net protein kcalories percent; the percent of the total energy value of the diet provided by protein.

Nutrient density: the nutrient composition of food expressed in terms of nutrient quantity/100 kcal.

Nutritional assessment: measurement of indicators of dietary status and nutrition-related health status of individuals or populations.

Obesity: excess fat stores; overweight individuals have more than 15 but less than 20% of their body mass as fat; obese individuals have more than 20% of their body mass as fat. Body fatness may not always be reflected by the body weight of the individual.

Postprandial: after a meal.

Quantitative computed tomography: an imaging technique consisting of an array of x-ray sources and radiation detectors aligned opposite each other. As x-ray beams pass through a body they are weakened or attenuated by the tissues of that body. The signals are then compared with a computer that uses the information to construct a model of the body and estimate its fatness as well as its composition. This instrument is a very sophisticated (and expensive) way to determine body fatness.

Respiratory quotient (RQ): ratio of CO_2 produced to O_2 consumed.

Skinfold thickness: a double fold of skin and underlying tissue that can be used to estimate body fatness.

Thermic effect of food: heat production upon food consumption; sometimes referred to as diet-induced thermogenesis (DIT).

Thermogenesis: heat production; when stimulated by exposure to cold it is referred to as cold-induced thermogenesis and represents the extra energy the body generates to maintain body temperature. In rodents this extra heat is thought to be produced by the brown fat cells. In man there is evidence that both supports and denies this response of specialized fat cells to cold exposure.

Total heat production (HE): the energy lost from the body as a result of its metabolism. It can be measured directly or estimated from the gas exchange. The commonly accepted equation for the indirect computation of heat production from the respiratory exchange is HE (kcal) = 3.866 (liters O_2) + 1.200 (liters CO_2) – 1.431 (g urinary nitrogen) – 0.518 (liters CH_4).

True digestive energy (TDE): the intake of energy minus the fecal energy of food origin (FiE = FE – FeE – FmE) minus heat of fermentation and digestive gaseous losses (TDE = IE – FE + FeE + FmE – HfE – GE).

True metabolizable energy (TME): the intake of food energy corrected for fecal loss and urine energy loss (TME = TDE – UE + UeE).

Urinary energy (UE): the gross energy of the urine. Represents the energy of nonutilized absorbed compounds from food (UiE), endproducts of metabolic processes (UmE), and endproducts of endogenous origin, i.e., creatinine, urea, uric acid, etc.(UeE).

TABLE 34.2

Methods and Equations Used for Calculating Basal Energy Need

Method	Equation
1. Heat production, direct calorimetry	kcal (kJ)/m² (surface area)
2. Oxygen consumption; indirect	O_2 cons./$W^{0.75}$
3. Heat production; indirect	Insensible Water Loss (IWL) = Insensible Weight Loss (IW) + (CO_2 exhaled – O_2 inhaled)
	$\text{Heat production} = \text{IWL} \times 0.58 \times \left(\frac{100}{25}\right)$
4. Energy used; indirect	$\text{Basal energy} = \frac{\text{Creatinine N (mg / day)}}{0.00482\ (W)}$
5. Estimate (energy need not measured) (Harris Benedict equation)	BMR = 66.4730 + 13.751W + 5.0033L – 6.750A (men)
6. Estimate (energy need not measured)	BMR = 655.9055 + 9.563W + 1.8496L – 4.6756A (women)
	$\text{BMR} = 71.2W^{0.75}\left[1 + 0.004(30 - A) + 0.010\left(\frac{L}{W^{0.33}} - 43.4\right)\right]$ (men)
	$\text{BMR} = 65.8W^{0.75}\left[1 + 0.004(30 - A) + 0.018\left(\frac{L}{W^{0.33} - 42.1}\right)\right]$ (women)

Abbreviations are as follows: W = weight in kg; L = height in cm; A = age in years.

See Heshka, S., Feld, K., Yang, M et al. *JADA* 93: 1031, 1993 for a comparison of various prediction equations.

Reference

1. Subcommittee on Biological Energy, National Research Council, *Nutritional Energetics of Domestic Animals* Nat. Acad. Press, Washington, DC, 1981.