



## **Weight Management, Energy Metabolism, and Endocrine Hormones- Review Article**

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### **Abstract**

Energy expenditure is determined by basal metabolic rate, physical activity, and Thermic Effect of Foods (TEF). Some endocrine hormones have role in basal metabolism and hence in human energy expenditure. And some foods pose more thermic effects on the total body energy expenditure and therefore can influence body weight. This review was performed to discuss factors which may affect body metabolism and body weight. Latest medical databases and nutrition and metabolism books were reviewed. We used the following keywords in online databases: "Weight Management" and "Hormones"; "Energy Metabolism" and "dietary factors"; "Weight Management" and "dietary factors"; "Endocrine Hormones" and "energy expenditure"; "Basal Energy Expenditure" and "dietary factors"; "Thermic Effect of Foods" and "dietary factors". The best designed articles were used to perform this review. The results are presented below. Spicy foods, Caffeine, and alcohol are some dietary factors and Body Size, Body Composition, Age and Gender are the non-dietary factors which may affect the metabolism. Diet composition can also slightly influence the metabolism. This effect depends on how efficient a dietary component is metabolized in the body. Regular dietary pattern also can slightly increase TEF comparing with irregular dietary pattern. Thyroid hormones, Ghrelin, Epinephrine, Cortisol, Steroid hormones, Leptin, Growth hormone, and insulin are among the most important hormones which may influence on metabolism and body weight. Energy expenditure is the basis for measuring human energy requirement and is crucial for weight management. Various hormonal, dietary and non-dietary factors are engaged in total body energy expenditure and are important for weight management.

**Keywords:** Weight Management, Energy Metabolism, Dietary factors, Endocrine Hormones

### **Introduction**

In order to access a successful weight management first we should be aware of individual energy requirements. On the other hand, human energy requirement is essentially determined by the amount of energy expenditure not only energy intake. Moreover, various metabolic and hormonal factors may affect the energy expenditure and

this is the point where endocrinology is intersecting with the story of weight management.

The importance of measuring energy expenditure as the basis for human energy requirement is stated in the report of Food and Agriculture Organization/World Health Organization/United Nations University on energy and protein requirements published in 1985. This report clearly rec-

ommended the use of energy expenditure rather than energy intake as the basis for determining energy requirements in humans (1).

Body weight is a good indicator of recent energy adequacy or inadequacy in a way that consumption of unbalanced amounts of energy in a period of time leads to body weight changes. Thus body-weight reflects adequacy of energy intake (2).

Simple definition of human energy requirement can be as the dietary energy which is necessary to maintain energy equilibrium in a healthy person of a determined age, gender, weight, height, and level of physical activity. Concerning children, pregnant and lactating women, energy requirements include the additional needs for the genesis of new tissues or the production and secretion of milk at rates eventuating a good health (2).

### ***Building Blocks of Energy Expenditure***

Classically, human daily total energy expenditure (TEE) is partitioned into three compartments: basal metabolic rate (BMR), thermic effect of food (TEF), and activity thermogenesis. The largest component of total energy expenditure is BMR (1) and typically represents approximately 60% to 70% of the TEE (2). Thermic effect of food is responsible for about 10% of TEE, while the rest and most unsteady part of TEE is activity thermogenesis which highly depends on activity level.

### ***Basal Energy Expenditure vs. Resting Energy Expenditure***

There is a little difference between basal energy expenditure (BEE) and resting energy expenditure (REE). Basal energy expenditure is defined as the least amount of energy consumed that is indispensable for sustaining life. In other words, a person's BEE is reflective of the amount of energy expended across 24 hours in a thermo neutral environment and inactive (physically and mentally resting), awake and fasting state (2).

Basal metabolic rate is the measurement of BEE in very harsh situations. Its measurements should be performed early in the morning, before the person has engaged in any physical activity and 10 to 12 hours after the ingestion of any food and

drink, or nicotine use. It may be determined directly by measuring the heat production using a direct calorimeter or indirectly by analysis of the end products of oxidation within the organism or by the other words from the amount of oxygen utilization and carbon dioxide production by a person.

If any of the conditions for the BMR are not met, energy expenditure measures should be referred to as the resting metabolic rate (RMR) which is representative of resting energy expenditure. Resting energy expenditure is the energy expended in the activities necessary to sustain normal body functions and homeostasis. These activities include respiration and circulation, the synthesis of organic compounds, the pumping of ions across membranes, the energy required by the central nervous system, and the maintenance of body temperature (2).

Measuring the BMR is not routine in usual clinic settings. RMR measurements are used instead, which in most cases about 10% to 20% are higher than BMR (2).

The difference of BMR measures between subsequent days is remarkably inconsiderable in men, (2), while its measures are not stable in all women. In fact day to day variances of BMR in women are affected by menstrual cycle and BMR may decrease gradually along with luteal phase progress (1).

### ***Resting Energy Expenditure determinants***

Several factors may affect the REE in different ways. The most important variables include body size and composition; but age, sex, and hormonal status also affect REE (2). Vast diversity of these factors in different people is the reason why REE is different among every two individuals. Here we discuss these variables briefly.

### ***Body Size***

Body surface area is an important determinant of this factor. Metabolic rate is higher in people with greater surface area. Suppose a situation where the weight of two individuals is equal but one of them is taller, the taller person with the larger body surface area has the higher metabolic rate. Total body

size is highly correlated with the amount of lean body mass (3).

### ***Body Composition***

The metabolically active tissue in the body is lean mass or fat-free mass (FFM) which is highly correlated to REE. About 80% of differences in REE can be attributed to FFM variances in various people (4). Athletes which have greater muscular mass are good examples for this concept. Their REE is about 5% higher than nonathletic individuals (2).

### ***Age***

Up to second year of life which the infant is growing rapidly and synthesizing new tissues, weight adjusted RMR is highest (5). As time goes by the child becomes older, the caloric requirement for growth is declined, and RMR is reduced in a FFM depended manner. Then after adulthood RMR is reduced in a rate of about 1% to 2% per kilogram of FFM per decade. As protective of lean body mass, physical activity can be helpful to maintain a higher RMR (2).

### ***Gender***

Differences in body size and composition between men and women are the leading reason why metabolic rates are not even in two genders. Men usually are more muscular and, their RMR are about 5% to 10% higher than women of the same weight and height (2).

### ***Caffeine, nicotine, and alcohol***

Caffeine, alcohol, and nicotine use may stimulate metabolic rate.

### ***Hormonal Status***

Resting metabolic rate is influenced by some endocrine disorders and hormonal status of human body via different mechanisms which we discuss briefly here. First of all and more obviously are thyroid hormones:

### ***Thyroid hormones***

According to consisting of a great number of studies done over the past century, we can be sure that thyroid hormones play a major role in the

determination of energy expenditure in human (6). This is especially obvious within endocrine disorders such as hyperthyroidism and hypothyroidism, in which body weight may decrease or increase as a result of RMR increment or decrement, respectively (2).

The major tasks of these hormones in the humans may attribute to growth, development, and thermogenesis (7). As it will be discussed later, obligatory thermogenesis is considered as the component of energy expenditure, and it is affected by thyroid hormones. Recent studies on rodents suggest important roles for thyroid hormones in both diet-induced adaptive thermogenesis (thermic effect of food), and the activity thermogenesis. Influences of thyroid hormone on energy expenditure are no longer assumed to be confined to obligatory thermogenesis (6). Thyroid hormones provoke some mitochondrial enzymes (such as succinate dehydrogenase, mitochondrial 3-phosphate glycerol dehydrogenase and lipogenic enzymes), uncouple cellular metabolism from adenosine triphosphate (ATP) synthesis and increases oxygen consumption (6-8).

As measured by indirect calorimetry; other evidences are obtained in studies of patients which need chronic thyroid hormone replacement. Different cellular mechanisms affected by T3 and T4 are exist. Even minute changes in thyroxine (T4) dosage were responsible for significant changes in resting energy expenditure. Unchanging plasma T3 levels in these patients indicate that there are some mechanisms of energy expending which depends on T4 (6). On the other hand, Several cellular 3, 3'-triiodothyronne (T3)-sensitive processes that are substantial determinant of cellular and subsequently whole body metabolism exist but which of these processes are the most importantly relevant to energy metabolism are still unknown (6).

In hyperthyroidism a subtle interaction between thyroid function and ghrelin has been reported in which ghrelin levels are reversibly suppressed. On the other hand hypothyroidism may increase ghrelin secretion (9). Ghrelin is implicated in the regulation of short- and long-term energy balance.

### *Ghrelin, regulation of appetite and macronutrient intake*

Ghrelin, a 28-amino-acid gastrointestinal peptide, has characteristics of adipogenic, growth hormone-releasing, and appetite-stimulating. It was first identified as the endogenous ligand for the hypothalamic-pituitary growth hormone secretagogue receptor type 1a (GHSR1a), stimulating the anterior gland of pituitary to produce growth hormone (GH). In fact, after hypothalamic GH releasing hormone and somatostatin, ghrelin is third-ranking in physiologic regulation of endogenous GH secretion(10). Subsequent studies revealed that appetite adjustment and energy homeostasis is one of the most important roles of ghrelin (11). It plays a great role for long-term energy balance and short-term food intake. Moreover its role as an influential signal for initiation of food intake is accepted. Ghrelin levels rise harshly preceding feeding onset, and are strongly blocked by food consumption. Ghrelin response following a meal is absolutely dependent to the specific macronutrient consumed in normal weight subjects, but is somewhat independent of macronutrient composition in obese people.

Considerable numbers of clinical studies have used iso-energetic test meals in order to examine the relative efficacy of each macronutrient to suppress postprandial ghrelin. In lean individuals, iso-energetic meals of different macronutrient content suppress ghrelin to a variable extent. Carbohydrates seem to be the most effective macronutrient in terms of postprandial ghrelin suppression, perhaps so of its glucose-elevating and insulin-secreting effect. But, new investigations show that carbohydrate ingestion may arouse a postponed ghrelin response in the subsequent post absorptive period, challenging the role of carbohydrate-rich meals in weight reduction diets. Additionally, all kinds of carbohydrates are not effective equally. Fructose rich servings of food suppress the ghrelin hormone inadequately, supporting the unending consumption of foods greater than before (especially sugary foods and beverages), over weight and obesity. Dietary proteins look to be the most satisfying macronutrient. All types of proteins can provoke prolonged ghrelin suppression and elevation of gut-derived anorexigenic hormones that delay gastric

emptying. In normal weight as well as obese subjects, to the extent that fat is concerned, it may be the slightest efficient ghrelin-blocker. In fact, fats can decrease ghrelin concentrations, but later or more weakly than other macronutrients. Simultaneously, other studies report that fat enriched foods have absolutely no effect on postprandial ghrelin levels.

The chief meal-induced mediators of ghrelin regulation are glucose, insulin, gastrointestinal hormones released in the postabsorptive phase, vagal activity, gastric emptying rate, and postprandial alterations in intestinal osmolarity. In obese subjects, postprandial ghrelin response is modified, and the macronutrient impact on ghrelin levels relatively seems to be ineffective. By weight reduction, ghrelin response returns to a previous condition and ghrelin-mediated appetite regulation significantly improves. Henceforward, it might be arousing curiosity to appraise the effect of dietary manipulation of specific macronutrients on fasting and postprandial ghrelin levels in long-term approach. Additional parameters that could possibly influence ghrelin response and should be further investigated are food form and viscosity (liquid, solid, semi-solid products), portion size and meal duration (11).

### *Epinephrine*

This hormone is a sympathomimetic which is synthesized in the adrenal medulla. It is being released during periods of emotional excitement or stresses, provokes the alpha- and beta- adrenergic systems, brings about systemic vasoconstriction and gastrointestinal relaxation, arouses the heart, and dilates bronchi and cerebral vessels, stimulates glycogen degradation (glycogenolysis) to provide sufficient glucose to all body organs. Epinephrine increases ATP production in heart by preferentially increasing pyruvate dehydrogenase complex activity and hence glucose metabolism (oxidation) (12). Induction of all these processes puts on a subtle increment on RMR (2).

### *Cortisol*

Cortisol is an important catabolic hormone and is the main glucocorticoid secreted by the adrenal cortex. Cortisol mobilizes glucose, free fatty acids, and amino acids from body pools and makes all

fuel substrates available to be metabolized. Hence, it may decrease fat free mass and may increase energy expenditure (13). Long-term glucocorticoid surplus as it can be seen in Cushing's syndrome decreases lean body mass, and its short-term surplus increases degradation of whole-body proteins. Some investigators showed about 10% reductions in energy expenditure after cortisol withdrawal (13).

### ***Steroid hormones***

Regulation of energy metabolism is one of the main roles of steroid hormones which are conducted by mitochondrial processes of oxidative phosphorylation (14).

Women periodically, have usual and subtle weight fluctuations near the time across ovulation and the onset of menstruation. These observations persuaded some investigators to pay attention to the menstrual cycle effects on RMR. Some of them found that during the luteal phase metabolic rate increases gradually. An average of 359 kcal/day differences in the BMR has been measured between its low point, about 1 week before ovulation at day 14, and its high point, just before the onset of menstruation. The approximate mean increase in energy expenditure is 150 kcal/day during the second half of the menstrual cycle (15). During pregnancy, RMR decreases in the early stages, but uterine, placental, and fetal tissue growth, as well as increasing of mother's cardiac work during this period leads to slightly increments in RMR (2).

### ***Leptin***

Leptin, the *ob* gene product, is synthesized and secretes from fat mass and may affect central nervous system, especially hypothalamus, to handle many of its functions. It may act as an afferent satiety signal which may affect the hypothalamus, to control food intake, metabolic rate and eventually regulate adipose tissue of the body (16). Leptin's action has been studied in vivo and obese individuals but its role during weight loss periods is indistinct (17). Some researchers have shown that serum leptin concentrations are a positive determinant of RMR (15).

### ***Growth hormone***

Still controversial, but not any relationship has been proved between RMR and endogenous growth hormone levels among healthy adults (2).

### ***Other hormones***

Other hormones such as insulin (15) also may influence the metabolic rate but a little evidence is present and further investigations are needed.

### ***Thermic Effect of Food***

The thermic effect of food (TEF) also commonly known as diet induced thermogenesis (DIT), specific dynamic action (SDA), and the specific effect of food (SEF) is the increment in energy expenditure above resting energy expenditure due to food consumption. In fact it involves processes of food digestion, absorption, metabolism and storage. TEF is divided into obligatory and facultative (or adaptive) subcomponents.

Obligatory thermogenesis is the energy necessary for digestion, absorption, and metabolizing (production and storage) of carbohydrates, fats and proteins. Adaptive or facultative thermogenesis is the "excess" energy expended in addition to the obligatory thermogenesis and is thought to be attributable to the metabolic inefficiency of the system stimulated by sympathetic nervous activity. The TEF typically represents about 10% of TEE (2).

### ***Determinants of Thermic Effect of Food*** ***Diet composition***

Diet composition can significantly influence the TEF. This effect depends on how efficient a dietary component is metabolized in the body. Fat for example is metabolized and stored in fat store pools of the body very efficiently with just 4% wastage, while carbohydrate wastage percentage to convert to fat mass and store in the body is about 25%. In all, carbohydrates and proteins can increase TEF more sharply than fats.

In fact this is one of the reasons why fats are more fattening than proteins and carbohydrates (18).

### **Spicy foods**

Spicy foods also can affect the TEF. They may increase the TEF with a permanency of a few hours. Meals with chili and mustard for example, may enhance the metabolic rate by 33%, with permanency of more than 3 hours (19).

### **Regular dietary pattern**

Women who eat in a regular pattern have a higher TEF response than women who do not follow any regular dietary pattern (20).

### **Activity Thermogenesis**

Physical activity thermogenesis is divided in to two compartments. The first part is the energy expended during physical activity which is called activity thermogenesis (AT); and the second part is the energy expended during usual daily activities other than volitional exercise. The later is called as nonexercise activity thermogenesis (NEAT) (21). Examples of NEAT include walking to work, shopping, home cleaning, playing guitar, dancing and even gum chewing. This part of AT which is life style depended may account for wide variances in energy expenditure among different individuals (22).

The most changeable component of TEE is physical activity, which may devote as low as 100 kcal/day in sedentary people or as high as 3000 kcal/day in some athletes (21).

### **Factors Affecting Physical Activity Thermogenesis**

#### **FFM**

Body size, exercise habits, and level of fitness may affect activity thermogenesis. These relationships may be attributed to variations in FFM (2).

#### **Aging**

Muscle mass decrease as the process of aging proceeds and this gives AT a decline in amount (2).

#### **Gender**

Again in a muscle mass depended manner AT is generally higher in men than women (2).

### **Excess postexercise oxygen consumption (EPOC)**

Another factor which may affect the energy expenditure is the excess postexercise oxygen consumption (EPOC). The duration and severity of exercise may increase EPOC, and in turn elevate metabolic rate even after exercise has ceased. These effects may be related to the person, rather than to the activity (2).

## **Conclusion**

Energy expenditure is determined by basal metabolic rate, physical activity, and Thermic effect of foods. Some endocrine hormones, dietary and non-dietary factors have role in basal metabolism and hence in human energy expenditure. Energy expenditure is the basis for measuring human energy requirement and is crucial for weight management.

## **Ethical considerations**

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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The authors declare that there is no conflict of interest.

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