Fact sheet 1

Energy expenditure

Energy

Humans oxidise (metabolise) carbohydrate, protein, fat (and alcohol) to produce energy. The energy is needed:

- To maintain body functions - to breathe, to keep the heart beating, to keep the body warm and all the other functions that keep the body alive
- For physical activity - for active movement - muscle contraction
- For growth and repair, which require new tissues to be made.

Energy intake

Energy can be measured in either joules or calories. A joule (J) can be defined as the energy used when 1 kilogram (kg) is moved 1 metre (m) by the force of 1 newton (N). A calorie (cal) can be defined as the energy needed to raise the temperature of 1 gram of water from 14.5 to 15.50C. In practice, both units are used just as different units are used to measure liquids, eg pints, litres. One calorie is equivalent to 4.184 joules.

People use large amounts of energy so nutritionists use larger units, called kilojoules

1 kilojoule (kJ) = 1,000 joules
1 megajoule (MJ) = 1,000,000 joules
1 kilocalorie (kcal) = 1,000 calories or 1 Calorie (Cal)

To convert from one unit to another:

1 kcal = 4.184 kJ
1 MJ = 239 kcal

The average daily energy intake in the UK is 10250kJ (2450 kcal) for men and 7030kJ (1680 kcal) for women. The energy in the diet is provided by carbohydrate, protein, fat and alcohol. The amount of energy made available to the body by each of these varies. A gram of carbohydrate (starch or sugar) provides 16kJ (3.75 kcal), protein provides 17kJ (4 kcal) per gram, fat provides 37kJ (9 kcal) per gram and alcohol provides 29kJ (7 kcal) per gram.

The source of energy in the diet has been implicated as a risk factor in certain diseases. Current recommendations from the Committee on Medical Aspects of Food and Nutrition Policy (1991) are shown in Table 1.0

Table 1.0 Suggested population averages for protein, carbohydrate and fat as a percentage of dietary energy.

Protein	**15**
Total Carbohydrate	**50**
Non milk extrinsic sugars*	**1**
Total fat	**35**
Saturated fatty acids	**11**
Polyunsaturated fatty acids**	**6.5**
Trans fatty acids	**2**
Monosaturated fatty acids	**13**

*NMES - free sugar not bound in foods, eg table sugar, honey and sugars in fruit juices, but excluding milk sugar.

** An individual maximum of 10% applies (with an individual minimum of 0.2% from linolenic acid, and 1% linoleic acid).

Alcohol should provide no more than 5% of energy in the diet.

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Energy expenditure

The energy expenditure (EE) of a man or woman over a whole day is often divided into different components, which can be individually determined. These are: basal metabolic rate (BMR), diet induced thermogenesis (DIT) and physical activity (PA) see Figure 1.0.

Basal Metabolic Rate (BMR)

BMR is the minimum amount of energy that a body requires when lying in physiological and mental rest. BMR is measured under standardised conditions, conducted with the subject in a post-prandial state (fasted for at least 12 hours), at complete rest in a thermoneutral environment (not too hot or cold). If one of these conditions is not met (e.g. shorter time interval for fasting) the measurement is usually termed resting metabolic rate (RMR).

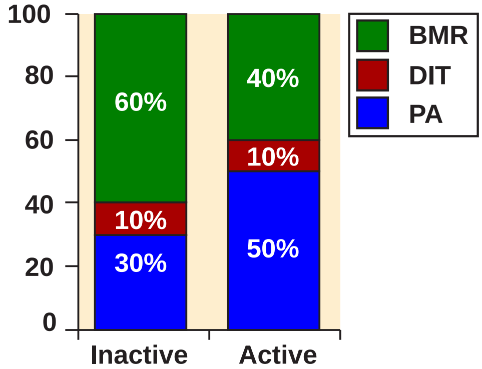

Figure 1.0 Total energy expenditure

BMR represents around 60-75% of total EE in many people. The main determinant of BMR is body weight and body composition. There is little evidence to support the claim that obesity is associated with a lower BMR. Infants and young children have a proportionately high BMR for their size due to their rapid growth and development. Men usually have a higher BMR than women since they tend to have more muscle. Older adults usually have a lower BMR than the young since the amount of muscle tends to decrease with age. BMR accounts on average for about three-quarters of an individual's energy needs.

Diet Induced Thermogenesis (DIT).

Also called post-prandial thermogenesis (PPT) or the thermic effect of food (TEF). DIT accounts for about 10% of total energy intake (EI) for a mixed western diet. This is the amount of energy utilised in the digestion, absorption and transportation of nutrients.

Physical Activity (PA)

PA is the most variable component of EE in humans. It includes the additional EE above RMR and TEF due to muscular activity and comprises minor physical movement (such as shivering and fidgeting) as well as purposeful gross muscular work or physical exercise. On average it accounts for 15 to 30% of total daily EE but can vary more in very active persons.

The total amount of energy required by individuals depends on the level of activity and on their body weight. The more active and heavier they are, the more energy they require. Table 2.0 shows the energy used up in various activities.

Table 2.0 Energy required for a variety of activities

Everyday Activities	KJ/min
Sitting	6
Standing	7
Washing, dressing	15
Walking slowly	13
Walking moderately quickly	21
Walking up and down stairs	38
Work and Recreation	
Light (most domestic work, golf, lorry driving, carpentry, bricklaying)	10-20
Moderate (gardening, tennis, dancing, jogging, cycling, digging)	21-30
Strenuous (cross-country running, football, swimming [crawl])	>30

Source: Ministry of Agriculture, Fisheries and Food. Manual of Nutrition. London: HMSO, 1992.

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The rates of EE during physical activity vary depending on intensity, duration, and frequency of the activity and on the body mass and fitness of the person performing the activity. There is currently a secular trend towards decreased physical activity in work time, which means that physical activity EE during leisure time is becoming more dominant in determining total EE. Thus physiology, behaviour and lifestyle play major roles in determining energy expended in activity.

The suggestion that the obese are more slothful than the lean has been reviewed, however, several analyses have shown that absolute daily energy expended by the obese is higher than that expended by the lean. This is, however, accounted for by the fact that the obese have to expend more energy in performing an identical task than the lean, since they must carry around additional weight. There is little evidence that obese subjects have low levels of PA compared to the lean, until fatness induces mobility problems. This tends to reflect the sedentary nature of modern lifestyles.

Measuring energy expenditure

Resting metabolic rate (ventilated hood) by indirect calorimetry

The term indirect calorimetry describes a method of estimating heat production based on the determination of gaseous exchange. Indirect caloriometry is based on the laws of thermodynamics, which firstly state that, “when the chemical energy content of a system changes, the sum of all forms of energy given off or absorbed by the system must be equal to the magnitude of the changes” (Dubois 1954).

The second basic principle of indirect calorimetry (Hess’s law of constant heat summation), states that, “heat produced in a chemical reaction is the same regardless of whether the process is direct or has intermediary steps”. This enables the enthalpy of oxidation of the fuel sources of the body to be calculated as the amount of molar oxygen consumed (e.g. kJ/l O_2 consumed), carbon dioxide produced and nitrogen excreted.

BMR can be measured by indirect calorimetry using a ventilated hood system (Deltatrac II, MBM - 200, Datex, Instrumentarium Corporation, Helsinki, Finland Figure 1.0). Subjects should be measured in the morning after an overnight sleep at the lab. They are required to refrain from any PA prior to measurement. Subjects are asked to rest for 10 minutes on the measurement bed, after which the ventilated hood is placed over the head during a 30-40 minute measurement period. Respiratory gases are measured at one-minute intervals and results recorded onto a floppy disc. Subjects are instructed to lie still but not to fall asleep.

Figure 1.0 Human Nutrition Unit volunteer undergoing a measurement

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The resulting values for oxygen uptake (VO_2) and carbon dioxide production (VCO_2) are automatically converted into energy values, calculated as:

RMR (kJ/24 hr) = [15.818 VO2 (l/min) + 5.176 VCO2 (l/min)] x 1440.

Where 15.818 and 5.176 are the energy equivalents of oxygen and carbon dioxide

Heart rate monitoring to calculate total daily energy expenditure

Minute-to-minute heart-rate (HR) monitoring can be used to determine total EE because it has been shown that an increase in HR during physical activity is associated with a linear rise in oxygen consumption. Thus, from continuously monitoring HR, VO_2 can be estimated as shown in figure 2.0 and using standard indirect calorimetric equations a relationship between HR and EE can be established for an individual.

Figure 2.0 Subject undergoing fitness test in the Human Nutrition Unit.

In periods of inactivity, factors such as emotional state, ambient temperature, humidity or smoking can easily alter heart rate without affecting VO2. Thus the correlation between heart rate and VO2 which is true for sub-maximal muscular work can not be applied for more sedentary activities such as sitting, lying, standing at rest.

Figure 3.0 below shows a graph of HR at four increasing workloads, exercising on an exercise bike. It shows that as workload increases, oxygen consumption increases and HR increases. At the bottom of the graph, it shows that the person’s resting heart rate while standing and sitting, was between 68 – 78 beats per minute. This was increased to around 138 bpm during exercise.

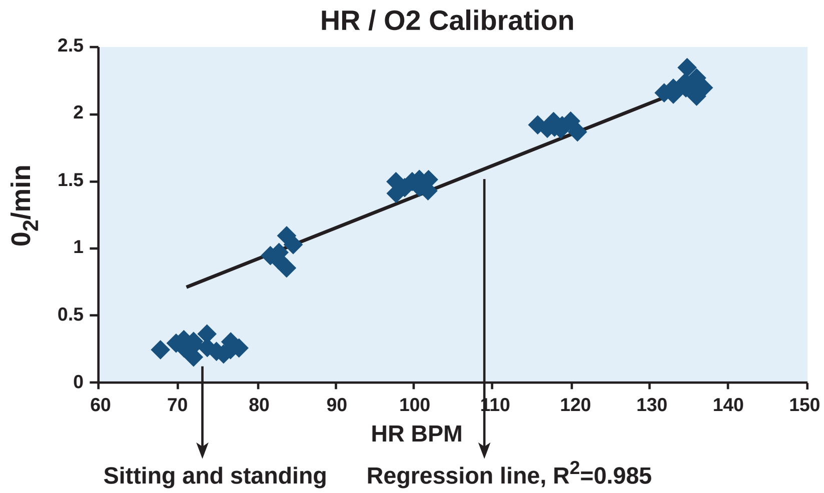

Figure 3.0. A typical example of the data collected during individual calibration of the HR-monitors

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How a HR calibration against oxygen consumption is carried out:

- 5 minutes sitting
- 5 minutes standing up
- 5 minutes cycling at the lowest possible resistance (50 watts) @60 rpm
- 5 minutes cycling to raise HR further (e.g. 75 watts)@ 60 rpm
- 5 minutes cycling to raise HR further (e.g. 100 watts)@ 60 rpm
- 5 minutes cycling to raise HR further (e.g. 125 watts)@ 60 rpm

Pedal speed remains constant at 60 revolutions per minute (RPM) throughout the test and resistance is gradually increased to elevate HR. During the last two minutes of each step when the HR was adjusted to the workload and was stable, breath-by-breath VO_2 and VCO_2 are measured with indirect calorimetry (Vmax29 metabolic cart, Sensor Medics, USA) using a mouthpiece and noseclip.

Total daily EE (TEE) can then be estimated according to the following equation:

TEE = SEDEE+SEE+AEE

Where: SEDEE = sedentary energy expenditure
SEE = sleeping energy expenditure (taken as 95% RMR)
AEE = activity energy expenditure

Subjects wear the heart rate monitor (HRM) continuously during waking hours during every day of the protocol. They do not wear the monitor during sleep at night. SEE is calculated as 95% of RMR and is applied to the time when the HR monitor is not worn (i.e. during sleep). SEDEE is assumed to be equal to the mean EE from the RMR, sitting and standing measurements during the calibration. EE is calculated using the treatment-specific regression equation (AEE) for each individual. Unphysiological high pulse rates (>220 BPM, which indicated interference) and zero values are removed and replaced by the average of the previous and subsequent values. It should be noted that there are considerable limitations to the use of HR monitors to estimate daily EE.

Physical activity and adults in Scotland

Physical activity levels are falling and there are major health concerns about the effects of physical inactivity. The majority of the Scottish population are either inactive, or only occasionally engage in light activity. Only 32% men and 22% women (1995) are achieving the moderate activity guidelines.

Physical activity makes an important contribution to health:

- Coronary Heart Disease - Physically inactive people have about double the risk of CHD.
- Stroke - Physical inactivity may be responsible for up to a three-fold increase in the risk of stroke.
- Osteoporosis - Regular activity reduces the risk of hip fractures by about 50%.
- Blood Pressure- Regular activity reduces blood pressure in those with hypertension.

Current Activity/Fitness Levels and Perceptions

The majority of the population don't do enough physical activity to benefit their health. 64% of men and 76% of women in the UK are either sedentary or are moderately active on an irregular basis only. Half of all adults think they do enough activity to keep fit. The Allied Dunbar National Fitness Survey, 1992 measured the physical activity levels and fitness levels of a representative sample of over 4000 English adults. This indicated that levels of cardio-respiratory fitness in the population were extremely low. Few people were routinely active at work, and only 20% men and 10% of women were in occupations requiring vigorous or moderately vigorous physical activity.

- Two-thirds of women and one-third of men find it difficult to walk briskly up a slight slope for several minutes.
- 25% of those who were active between the ages of 14 and 19 were still active, compared with only 2% who were inactive at that age.
- 80% of both men and women incorrectly believed they did enough exercise to keep fit.

How Much Physical Activity is Needed ?

Research has led to a consensus that an inactive life leads to increased risk of coronary heart disease, stroke and other health problems. The benefits of vigorous activity (activities that build up a sweat and some shortness of breath) are well known, and offers the best cardio protection, however there is a growing international consensus that regular moderate activity also confers health benefits. Studies have shown that moderate intensity activity is associated with improved fitness and lower risk of coronary heart disease.

The new government recommendation is intended to encourage the majority of the population, who do not exercise on a regular basis, to build physical activity of a moderate intensity into their daily routines.

Guidelines

In terms of intensity and duration, the strategy for the promotion of physical activity is: to encourage those people currently taking no physical activity to aim for one period of at least 30 minutes of moderate activity a week to encourage more people to take 30 minutes of moderate activity on a daily basis (at least five days a week), and to encourage those people already taking some vigorous activity, to take on average, three periods of vigorous activity of 20 minutes duration, a week.

	Vigorous Activity	Moderate Activity Message
Message	20 mins of vigorous activity, 3 times a week	30 mins of moderate activity on most days
Definition	Activity that leaves you sweaty and out of breath breath.	Activity that raises your heart rate and leaves you a little out of
Examples	Running, cycling, football, tennis, exercise class	Brisk walking, dancing, gardening, golf, bowling.

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