HANDBOOK ON HUMAN NUTRITIONAL REQUIREMENTS

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FOREWORD

The Food and Agriculture Organization of the United Nations (FAO) provides advice and assistance to member governments in their agricultural planning and development so as to ensure that their food supply meets the needs of the people. The World Health Organization (WHO) is concerned with the prevention of disease and the promotion of health. There are in the world many millions of poor persons, among them children, whose health especially suffers because of an insufficiency of the right kind of foods. On the other hand, there are diseases, common among prosperous people, which are associated with dietary excesses. The incidence of some of these diseases has increased in recent years, reaching epidemic proportions in many of the prosperous countries of the world.

For these reasons both FAO and WHO have been concerned with gathering statements on human nutritional requirements — as accurate and generally acceptable as possible — that will provide a sound scientific basis for the programmes and policies of their member governments. In the last twenty years the two organizations have convened eight meetings of Expert Groups, which have reported on energy requirements (calories) and the following essential nutrients: protein, vitamin A, vitamin D, ascorbic acid (vitamin C), thiamine, niacin, riboflavine, folates, cyanocobalamin (vitamin B_{12}), calcium, and iron. The texts of these reports run to hundreds of pages and contain much technical biochemistry, physiology, and clinical medicine. They are also concerned with the epidemiology of deficiency diseases and the ecology of man in relation to his food supply. Hence, the full reports are not easy reading for those whose knowledge of these subjects is limited. This handbook sets forth the specific recommendations for nutrient intakes made by these Expert Groups and aims to provide a commentary written in a language that is intended to be more readily understandable to food administrators, agricultural planners, and applied nutritionists. It is also hoped that this handbook will prove useful to teachers in secondary schools and colleges and to everyone concerned with health education.

The main task of correlating the reports of the meetings and of drafting this handbook was undertaken by Dr. R. Passmore, Dr. B.M. Nicol, and Dr. M. Narayana Rao — the latter two taking especial responsibility for the chapters on energy, proteins, iron, iodine, fluorine, and other trace elements. A first draft of the book was reviewed by Dr. G.H. Beaton and Dr. E.M. DeMaeyer, who made many valuable comments and suggestions which were taken into account in the preparation of the final version.

CONTENTS

1. RECOMMENDED INTAKES OF ENERGY AND NUTRIENTS

Foods supply the body with energy in the form of carbohydrate, fat, and protein; the alcohol in beers, wines, and spirits may also be utilized as a source of energy. Foods also provide the body with such materials as amino acids, vitamins, and minerals — all of which are needed for growth and for the maintenance of cells and tissue. Table 1 gives the recommended intakes of energy and eleven nutrients proposed by the FAO/WHO Expert Groups. The text of this handbook indicates for each nutrient the main foods in which it may be found and the effects on health which are likely to result from a deficiency or an excess of the nutrient. There are many other essential nutrients which the diet must supply, but these are present in ample amounts in all common diets. This text does, however, include brief notes on iodine and fluorine, since an insufficient intake of each of these elements is an important cause of ill health.

The recommended intakes are intended for the use of planners. With the aid of tables giving the composition of foods, the recommended intakes of nutrients can be converted into recommendations for average intakes of foods according to age, sex, and physiological status. Then, the total population figure of a country, together with the distribution of the population by age groups and sex, can be used to make estimates of the total national food requirements. Thus the FAO/WHO recommended intakes of nutrients serve as guides for government officials and others whose duty it is to plan agricultural production and to control imports and exports of food, in order to ensure that the food supply will be sufficient to meet the needs of the people. Such plans must aim to supply not only present requirements, but also those of the future — which are likely to be greater in most countries owing to population growth and increase in purchasing power.

The recommended intakes can also serve as a guide for drawing up ration scales for institutions, such as hospitals, orphanages, boarding schools, and prisons, as well as for the armed services. They may be useful as well in planning food for expeditions.

The figures for recommended intakes may be compared with actual consumption figures determined by food-consumption surveys. Such comparisons, though always useful, cannot in themselves justify statements that undernutrition, malnutrition, or overnutrition is present in a community or group, as such conclusions must always be supported by clinical or biochemical evidence. The recommended intakes are not an adequate yardstick for assessing health because — as will become apparent from the text — each figure represents an average requirement augmented by a factor that takes into account inter-individual variability. The recommended intakes are therefore the amounts considered sufficient for the maintenance of health in nearly all people.

Food wastage

It must be understood that the recommendations apply to amounts of nutrients required by people in their stomachs. For many foodstuffs the journey from the fields where they are grown to the homes where they are eaten is a long one, and nutrient losses may occur on the farm, in barns and warehouses, in food factories, and in wholesale and retail distribution. Estimates of such losses can be made at a national level.

Food losses also inevitably occur in the home due to spoilage, methods of cooking and preparing meals, or plate waste. In homes with poor cooking equipment and storage facilities such losses are often unavoidable. The extent of these losses is hard to measure or estimate. Plate waste is certainly closely related to food availability. In a home where food is scarce and the family often hungry not more than one percent may be wasted in this way. On the other hand, inspection of garbage cans outside some houses in affluent suburbs would suggest that such families acquire more food than their members consume. Ten percent is probably the representative figure for wastage in homes where reasonable care is taken.

SOME EFFECTS OF UNDERFEEDING AND OVERFEEDING

All mammals, including primitive man, developed in environments where the food supply was uncertain and temporary restrictions in food intake were a normal experience. Man has evolved with reserves and adaptive mechanisms which help him to survive periods of famine. His reserves of energy in the form of carbohydrate are small and may be exhausted by two days of starvation, but if he has been previously well fed, the reserves of fat supply sufficient energy to prevent death from starvation for two months or longer. By contrast, a man may die from cold in two or three hours or from lack of water in two or three days. These facts should help in fixing priorities when planning relief measures after a large natural disaster. For someone in good health two weeks with no food is a most unpleasant experience, but it has no permanent adverse effects on health, as participants in hunger strikes well know. If the period of food deprivation is prolonged, the need for energy is reduced by deliberate curtailment of all unnecessary physical activity; moreover, as starvation proceeds, the tissues waste and the body becomes smaller, thus needing less energy to maintain itself.

The body has no real store of protein; however, as a tissue wastes, the proteins in it are broken down and the constituent amino acids become available, at least in part, to maintain the protein in other and more essential tissues and cells. Furthermore, the cells, especially those of the liver, adapt so that the amino acids from a limited supply of protein can be utilized more readily for the function of maintenance and less as a source of energy. In a normal adult the protein losses from the body are not likely to become critical until the body weight has fallen by at least 25 percent, which usually does not occur before about two months of total starvation.

Most of the water-soluble vitamins are attached as cofactors or apoproteins. If the body lacks a supply of a vitamin from the outside, clinical signs of deficiency appear when a vital biochemical function has been impaired. Scurvy or beriberi or pellagra may be expected to appear after varying periods of time in a community suddenly cut off from a supply of ascorbic acid or thiamine or niacin, respectively. On the contrary, the liver of a healthy adult contains stores of vitamin B_{12} and vitamin A sufficient to last for many months or even years.

Only in recent years have some large communities had ample supplies of foods made easily available to them with little expenditure of physical energy. Furthermore, many foods have been made more than normally appetizing by artificial means. In such communities there is thus every possibility and temptation to eat more than is required. Since the body has no other means of disposing of excess energy in the food than by storing it as fat, obesity, with its adverse effect on health, is now widespread among children, adolescents, and adults in some countries.

Because excess dietary protein is readily converted into amino acids and subsequently used as energy, it does not accumulate in the body. The traditional diets of some communities — for example, the South American gauchos, the East African Masai tribe, and the Eskimos — consist almost entirely of meat and other foods of animal origin. These diets may provide 200 g of protein per day, more than double the normal intake, without causing any apparent harm. However, in new foods from unconventional sources, such as yeast and chlorella, a green alga which grows in the scum on ponds, the protein is associated with large amounts of nucleic acids. These break down to form uric acid, which may give rise to kidney stones if large quantities of such proteins are eaten.

Any dietary excess of the water-soluble vitamins is readily excreted in the urine; hence, poisoning from these vitamins is unknown. This method of disposal is not available to the fat-soluble vitamins, but very large amounts of vitamin A can be stored in the liver. Both vitamins A and D are, however, potentially detrimental, and the well-known effects of overdosage with medicinal preparations are to be discussed later in this text.

The minerals calcium and iron are required by the body in the manufacture of bone and haemoglobin, the pigment present in the red blood corpuscles. Both calcium and iron are present in the diet in much greater quantities than are needed by the body, whereas the kidneys can excrete into the urine only limited amounts of calcium and negligible amounts of iron. The body's requirements of these two minerals are met by means of two control mechanisms in the small intestine which regulate absorption, and the greater part of the dietary intake of both elements passes straight through the intestines and is lost in the faeces. The nature of neither of the two control mechanisms is well understood, but both normally work with precision. Certain diseases may cause them to break down, as a result of which insufficient calcium or iron is absorbed. Each mechanism has a large reserve capacity for rejecting an excess dietary intake, but under certain circumstances it may be inadequate.

It is very difficult to assess precisely the dietary needs for protein, vitamins, and minerals because individuals vary in their needs. For this reason, as has already been mentioned, the recommended intakes each include a safety factor. Any excess intake not required by the body is used in the case of protein as a source of energy, in the case of water-soluble vitamins excreted in the urine, in the case of vitamin A stored in the liver, and in the case of calcium and iron not absorbed in the small intestine but rejected in the faeces.

None of these considerations apply to energy intake in food. Each individual, so as to meet exactly his requirement, must be regulated by his appetite or his feeding habits. If his intake is for any reason below requirement, he becomes thin and wastes away; if his intake is above requirement, he becomes fat and is exposed to all the health hazards of obesity. Consequently there is no safety factor in recommendations for energy intake, although requirements may vary among individuals of the same sex and age.

2. ENERGY

The human body is an engine which can set free the chemical energy bound in fuels present in foods. These are carbohydrates, fats, proteins, and alcohol. Since the body continually converts and replaces its component parts, energy is needed for the synthesis of new organic substances in this continuing process of maintenance. The synthetic reactions which produce the chemical components of the new cells and tissues during growth also require energy, and the faster the rate of growth the greater the need for fuel. The body also has to have energy for internal work, such as the action of the heart in circulating the blood and the movements of the diaphragm in breathing. Less obvious is the work done in maintaining the concentrations of salts and ions in the cells and body fluids. Sodium and chloride are the main ions in the blood, and potassium and phosphate in the cells. The difference in the ionic composition of the fluids inside and outside the cells is essential to their normal functioning and can only be maintained by chemical reactions utilizing energy. All these processes constitute the resting energy exchanges, also known as *basal metabolism*, which is equal to the energy expenditure when the body is at complete rest.

Additional fuel is needed for external work performed by the muscles, such as moving the body about, maintaining its posture, lifting and carrying loads, and the varied physical activities of everyday life.

It is customary to express the energy content of foods and the energy requirements of man and animals in terms of kilocalories. A kilocalorie (kcal) is defined as the amount of heat required to raise the temperature of a litre of water from 15°C to 16°C. The new term for quantitatively expressing energy is *joule*. One joule is equal to the energy expended when one kilogram is moved through one metre by one newton (a force which accelerates 1 kg by 1 m/sec^2).

One kilocalorie is equal to 4.184 kilojoules (kJ). The energy content of diets and the energy requirements of humans usually exceed 1 000 kJ and are generally expressed in terms of megajoules (MJ).

The following factors may be used for converting calories to joules and vice versa:

1 kcal = 4.184 kJ	1 kJ = 0.239 kcal
1 000 kcal = 4 184 kJ	1 000 kJ = 239 kcal
1 000 kcal = 4.184 MJ	1 MJ = 239 kcal

The approximate energy values of the body fuels are the following: for carbohydrate, 4 kcal or 16.7 kJ per gram; for fat, 9 kcal or 37.7 kJ per gram; for protein, 4 kcal or 16.7 kJ per gram; and for alcohol, 7 kcal or 29.3 kJ per gram. These are net values, allowing for the small losses of energy in the faeces and also for the energy lost in the urine in the form of urea and other nitrogenous end-products of protein metabolism which cannot be completely broken up in the body.

The energy content of a foodstuff is obtained by applying the above factors to its carbohydrate, fat, protein, and — where applicable — alcohol content as determined by chemical analysis. Tables of food analysis are available for many countries and regions of the world, and there are, in addition, international and regional food-composition tables prepared by FAO, of which those for Latin America, Africa, East Asia, and the Near East are examples. Compilers of such tables may use slightly different and more accurate figures than those given above, which are only approximations, the figures being rounded off so that they can be remembered easily; but their use is unlikely to involve any serious error.

The subject of the metabolism of alcohol in humans and laboratory animals has been investigated from time to time. The purpose of these studies has been to determine whether alcohol may serve the same purpose in the energy economy as ordinary carbohydrate does in saving protein and in providing energy for muscular activity, the deposition of fat, and the generation of heat to maintain body temperature.

It has been observed that under conditions of moderate intake most of the potential energy of the ingested alcohol is available for muscular work and for the production of body heat. The partial replacement of carbohydrate or fat in the diet by an amount of alcohol equal in energy content has also been shown to be effective in the synthesis of body tissue.

The body can oxidize alcohol at a limited rate. A healthy, well-fed adult who in terms of body weight consumes alcohol in quantities of less than 2 g/kg in twenty-four hours oxidizes it at a constant but limited rate of about 100 mg/kg per hour. A 65-kg man and a 55-kg woman can thus obtain, respectively, 700 kcal (2.9 MJ) and 525 kcal (2.2 MJ) daily from alcohol.

ENERGY REQUIREMENTS OF ADULTS

It is convenient to consider the expenditure and thereby the requirements of persons of different occupation, age, and size by reference to a man and woman 25 years of age and weighing 65 kg and 55 kg, respectively. Assuming that one spends eight hours each in bed, at work, and in nonoccupational activities, the total energy expenditures of our reference man and woman can be calculated. Tables 2 and 3 illustrate how their energy expenditures may be distributed over twenty-four hours and the effect of occupation.

While at rest in bed the energy expended approximates the basal metabolic rate (BMR) — for the reference man a little over 1 kcal/min, and for the reference woman a little under 1 kcal/min. This rate is increased by about one-half when sitting and using the arms for light work. It is doubled when standing and moving about slowly, and quadrupled when walking at a brisk pace. Thus the rate of energy expenditure when one is on foot and carrying out domestic and everyday tasks is between two and four times the resting rate. Similar rates of work are found in light industry. With heavy work, such as using a pick and shovel or moving big loads, the rate may rise to eight times the resting level. Exceptionally heavy work in industry and first-rate performance in some sports may raise energy expenditure to sixteen times or occasionally twenty times the resting level, but such rates are possible only for specially trained persons and, then, only for short periods.

The energy expended during the eight hours at work is thus determined by occupation and affected only to a small degree by the individual. A rough classification of the different occupations by level of activity is given on the following page.

Light

Men: Office workers, most professionals (lawyers, doctors, accountants, teachers, architects, etc.), shop workers, the unemployed.

Women: Office workers, housewives with mechanical household appliances, teachers and most other professionals.

Moderately active

Men: Most men in light industry, students, construction workers (excluding heavy labourers), many farm workers, soldiers not on active service, fishermen.

Women: Workers in light industry, housewives without mechanical household appliances, students, department-store workers.

Very active

Men: Some agricultural workers, unskilled labourers, forestry workers, army recruits, soldiers on active service, mine workers, steel workers, athletes.

Women: Some farm workers (especially in peasant agriculture), dancers, athletes.

Exceptionally active

Men: Lumberjacks, blacksmiths, rickshaw pullers.

Women: Construction workers.

The energy expenditure per hour by men and women for light work is 140 and 100 kcal (0.58 and 0.41 MJ), respectively; for moderately active work, 175 and 125 kcal (0.73 and 0.51 MJ); for very active work, 240 and 175 kcal (1.0 and 0.74 MJ); and for exceptionally active work, 300 and 225 kcal (1.25 and 0.94 MJ).

The expenditure of energy during the recreational or nonoccupational period is determined in large part by individual choice. It can range anywhere between 700 and 1 500 kcal (3.0 and 6.3 MJ) for men and 580 and 980 kcal (2.4 and 4.1 MJ) for women for an eight-hour period, depending on the type of activity. In an industrial society an individual's energy requirements are determined more by his choice of recreation than by his occupation. Assuming that our reference man and woman engage in some moderately active recreations, their daily energy expenditure works out to 3 000 kcal (12.5 MJ) and 2 200 kcal (9.2 MJ), respectively.

In addition to physical activity and to the type and nature of non-occupational activities, the energy requirements of individuals depend as well on the following variables, which are interrelated in a complex way: (*a*) body size and composition; (*b*) age; and (*c*) climate and other ecological factors.

Body size and composition

Energy expenditure may be influenced by the effect of body size and composition on (*a*) resting metabolism, (*b*) the physical effort of moving the whole body or large parts of the body, and (*c*) the work of standing, of maintaining posture, and of small movements of the limbs. Also, the total physical activity of an individual may be influenced by the quantity of adipose tissue in his body. When the body composition is normal, the energy requirement of adults per unit of body weight is the same: for moderately active men 46 kcal (0.19 MJ) per kilogram of body weight, and for moderately active women 40 kcal (0.17 MJ) per kilogram of body weight. The energy requirement of very active and exceptionally active men and women per unit of body weight is much higher. Because women have a larger proportion of fat, their energy requirement is less than that of men.

Age

The energy expenditure of adults may alter with age because of (*a*) changes in body weight or body composition, (*b*) a decrease in the basal metabolic rate, (*c*) a decline in physical activity, and (*d*) an increasing prevalence of disease and disabilities. In many populations the amount of body fat and the total body weight tend to increase with age; this may affect the basal metabolism and, hence, the total energy requirements.

There is little evidence that physical activity, either at work or at leisure, alters significantly between the ages of 20 and 39. From the age of 40 onward several changes may occur. Older people tend to leave work that requires high energy expenditure or to be less active in such occupations. Even in occupations with moderate