
Dietary reference intakes

**energy, proteins, fats, and digestible
carbohydrates**

Gezondheidsraad

Health Council of the Netherlands

To the Minister of Health, Welfare and Sport

Subject : submission of new dietary reference intakes
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Dear Minister,

I hereby submit new recommendations for the dietary intakes of energy, proteins, fats, and digestible carbohydrates. A committee of the Health Council has drawn up these recommendations, and the Standing Committee on Nutrition and the Standing Committee on Medicine have reviewed them. These recommendations are the second issue in a series, the purpose of which is to revise the Dutch dietary reference intakes that were established in 1992 by the former Food and Nutrition Council. Dietary reference intakes are a vital part of the provision of nutrition education.

I would like to take this opportunity to highlight three points that I consider to be of particular importance within the context of the recommendation. Firstly, I fully support the Committee's view that an excessive energy intake, often in combination with a relatively inactive lifestyle, is the major cause of overweight. Secondly, I support the balanced approach to the desirable total amount of fats in the diet. I emphasize that, in the new recommendation, the advice for total fat intake for overweight individuals differs from that for individuals with a desirable body weight. Thirdly, I like to stress that, in the interests of public health, it is vital that there be a reduction in the consumption of saturated and *trans* fatty acids in the Netherlands. Consumers have little or no influence on the fatty acid composition of certain food products, from which a large proportion of the saturated fatty acids in the diet are derived. Accordingly, I urge industry to push ahead with innovative developments aimed at improving the fatty acid composition of food.

Today, I have also submitted these new recommendations to the Minister for Agriculture, Nature Management and Fisheries.

Yours sincerely,
(signed)
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Dietary reference intakes

energy, proteins, fats, and
digestible carbohydrates

to:

the Minister of Health, Welfare and Sport

the Minister for Agriculture, Nature Management and Fisheries

No. 2001/19ER, The Hague, 18 July 2001 (corrected edition: June 2002)

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Contents

Executive summary 9

1 General introduction and used concepts 15

2 Energy 41

3 Proteins 63

4 Fats 79

5 Digestible carbohydrates 135

Annexes 149

A Committee and working group 151

B Dietary reference intakes in other reports 155

C Intake of energy and the nutrients dealt with in this recommendation 161

Executive summary

In 1992, the former Food and Nutrition Council of the Netherlands published dietary reference intakes. These were primarily aimed at the prevention of deficiency symptoms. In recent years, increasing numbers of studies have shown that certain nutrients can help to prevent chronic diseases. Partly as a result of this, it became necessary to review the dietary reference intakes. The Health Council's Committee on Dietary Reference Intakes, which is charged with this task, sets out its findings in a series of recommendations. The first recommendation, containing the dietary reference intakes for calcium, vitamin D, thiamin, riboflavin, niacin, pantothenic acid and biotin, was published in July 2000. The present recommendation, the second in the series, contains the dietary reference intakes for energy, as well as for proteins, fats and digestible carbohydrates (the so-called macronutrients). These are the substances in the diet that provide energy, and for which the body has a physiological requirement. Although alcohol also supplies energy, it has not been included in this recommendation. The link between energy and the macronutrients is expressed in many dietary reference intakes, by describing nutrients in terms of energy percentage. This is the nutrient's contribution as a percentage of the total energy intake.

The term 'dietary reference intakes' is a collective term for the estimated average requirement, recommended dietary allowance, adequate intake and tolerable upper intake level. The requirement for a nutrient is the intake that prevents symptoms of deficiency and that keeps the risk of chronic disease as small as possible. Given a requirement with a normal distribution, the estimated average requirement is the level of intake that is adequate for half of the population. The recommended dietary allowance

is calculated as the estimated average requirement plus twice the standard deviation of the requirement. This intake is adequate for virtually all of the individuals in the group in question. Even where the estimated average requirement is unknown, the Committee determines the level of intake that is sufficient for the entire population. In such cases, the Committee refers to 'adequate intake' rather than 'recommended dietary allowance'. Finally, the Committee specifies the tolerable upper intake level. This is the level of intake above which there is a chance that adverse effects will occur.

The dietary reference intakes are intended for use by the healthy section of the population. The Committee gives separate values for infants, young children, adolescents, adults and the elderly. In many cases, the Committee makes distinctions on the basis of gender. It has also established dietary reference intakes for pregnancy and lactation. The two tables at the end of this summary contain all of the dietary reference intakes that have been derived in this recommendation. In this executive summary, the major changes relative to the previous Dutch dietary reference intakes are discussed, as are the differences with dietary reference intakes in use in foreign countries.

In order to prevent overweight and undesirable weight gains, it is of crucial importance that everyone's energy intake conform to their personal requirement. The Committee provides formulae that individuals can use to estimate their personal energy requirement on the basis of age, body weight and level of physical activity. In the case of energy, the Committee provides just one dietary reference intake: the estimated average requirement.

The recommended dietary allowances for protein, which are lower than in the previous Dutch values, now show greater conformity with those in other countries. The values for healthy adults with a mixed diet are around ten percent of the energy intake. The recommended dietary allowances for individuals with a lacto-ovo vegetarian dietary pattern and a vegan dietary pattern are respectively 1.2 and 1.3 times higher than the values derived in the recommendation. This is because the protein quality of these dietary patterns is a little less than in diets that include meat or meat products. The tolerable upper intake level for proteins is 25 percent of the energy intake.

With regard to the total consumption of fat, the Committee distinguishes between people with an optimum weight and those who are overweight or who experience undesirable weight gains. This is a new element, relative to foreign dietary reference intakes and to previous Dutch dietary reference intakes. For individuals whose weight is optimum and constant, the Committee feels that any level of intake between 20 and 40 percent of total energy intake is adequate.

The Committee cites the same lower limit for individuals who are overweight or who experience undesirable weight gains, however the upper limit is lower (20 to 30 or 35 percent of total energy intake). The reason for this distinction is the finding that a

low-fat diet can lead to a reduction in weight or can combat the weight gain with increasing age. Energy, rather than fat, is the deciding factor in this case. Even those on a low-fat diet can become overweight if their energy intake is excessive. However, individuals on a high-fat diet are more likely to consume excessive amounts of energy. The effect on body weight is quite modest. A diet in which the amount of fat has been reduced by one quarter (30 percent of energy intake rather than 40 percent) produces an estimated average reduction in body weight of two to three kilograms. The Committee feels, however, that even this slight effect on body weight can contribute to the prevention of diabetes mellitus type 2 and (to a lesser extent) coronary heart disease. In the Netherlands, the growing problem of overweight needs to be tackled on a variety of fronts. In this connection, the Committee also mentions the importance of adequate levels of physical activity.

In addition to the dietary reference intakes for total fat consumption, the Committee has focused to a large extent on the composition of dietary fat*. This involves saturated fatty acids, *trans* fatty acids, monounsaturated fatty acids and (some) polyunsaturated fatty acids. The Committee recommends that the intake of saturated fatty acids and *trans* fatty acids should be as low as possible, since these substances increase the risk of coronary heart disease. The tolerable upper limit is ten percent of energy intake for saturated fatty acids and one percent of energy intake for *trans* fatty acids. This dietary reference intake implies that 90% of the Dutch population must reduce their intake of these fatty acids. The risk of coronary heart disease can be reduced by replacing saturated fatty acids with unsaturated fatty acids. Most of the fat consumed should therefore consist of monounsaturated and polyunsaturated fatty acids. The Committee sees no reason to limit the intake of monounsaturated fatty acids. For all of the polyunsaturated fatty acids together, it recommends a tolerable upper limit of 12 percent of energy intake. If an amount of linoleic acid equivalent to at least two percent of energy intake is consumed then the risk of deficiency will be zero. Although some studies associate the consumption of large quantities of alpha-linolenic acid with an increased risk of prostate cancer, the Committee takes the view that there is insufficient scientific evidence for this adverse effect. In view of the beneficial effect on the risk of coronary heart disease, the Committee proposes the following adequate intakes for adults: alpha-linolenic acid, one percent of energy intake, and n-3 fatty acids from fish, 0.2 grams per day. This adequate intake for alpha-linolenic acid is relatively high compared to that used in foreign dietary reference intakes.

The recommended dietary allowances for digestible carbohydrates (40 percent of energy intake in the case of adults) are lower than the adequate intakes quoted in the previous Dutch dietary reference intakes and in foreign recommendations. The reason

* An explanation of fatty-acid terminology is given in sections 4.1.1 and 4.1.2.

for this is that the Committee works on the basis of an estimate of the carbohydrate requirement, while most other recommendations treat carbohydrates as a way of balancing the energy needs. The Committee has set no upper limit for carbohydrate intake.

Dietary reference intakes for all age groups up to one year of age, for pregnancy and lactation.

nutrient	dietary reference intake ^a	gender ^b	unit ^c	age in months			pregnancy	lactation
				0-2	3-5	6-11		
energy	EAR	M/F	MJ/[kg.d]	0.39	0.35	0.35	-	-
	EAR	F	MJ/d	-	-	-	+1.2 ^d	+2.1 ^e
proteins	RDA ^f	M	g/d	9	10	10	-	-
	RDA ^f	F	g/d	8	9	10	62	65
	RDA ^f	M	en%	8	7	6	-	-
	RDA ^f	F	en%	8	6	6	9	9
	UL	M/F	en%	10	10	15	25	25
fats	AI	M/F	en%	45-50	45-50	40	see M/F ≥ age 4	
	UL	M/F	en%	-	-	-	see M/F ≥ age 4	
• linoleic acid ^e	AI	M/F	g/[kg.d]	0.6	0.6	-	-	-
	AI	M/F	en%	-	-	2	2.5	2.5
• alpha-linolenic acid ^e	AI	M/F	g/[kg.d]	0.08	0.08	-	-	-
	AI	M/F	en%	-	-	1	1	1
• docosahexaenoic acid ^e	AI	M/F	g/[kg.d]	0.02	0.02	-	-	-
• n-3 fatty acids from fish ^e	AI	M/F	g/d	-	-	0.15-0.2	0.2	0.2
• arachidonic acid ^e	AI	M/F	g/[kg.d]	0.04	0.04	-	-	-
• polyunsaturated fatty acids ^g	UL	M/F	en%	-	-	12	12	12
• monounsaturated and polyunsaturated fatty acids ^{g,h}	AI	M/F	en%	-	-	-	see M/F ≥ age 4	
• saturated fatty acids	AI	M/F	en%	25	25	-	a.l.a.p. ⁱ	a.l.a.p.
	UL	M/F	en%	-	-	20	10	10
• trans fatty acids	AI	M/F	en%	-	-	-	a.l.a.p.	a.l.a.p.
	UL	M/F	en%	-	-	-	1	1
carbohydrates	AI	M/F	g/[kg.d]	10	10	-	-	-
	RDA ^f	M/F	en%	-	-	50	40	40

^a EAR = estimated average requirement
RDA = recommended dietary allowance
AI = adequate intake
UL = tolerable upper intake level

^b M = boys and men
F = girls and women

^c en% = percentage of total energy intake

^d based on a reduced level of physical activity during pregnancy

^e based on an average metabolic combustion of 0.5 kg of body fat per month during lactation

Dietary reference intakes for age groups above one year of age.

nutrient	dietary reference intake ^a	gender ^b	unit ^c	age in years							
				1-3	4-8	9-13	14-18	19-30	31-50	51-70	>70
energy	EAR	M/F	MJ/d	5.0	7.2	10.6	14.0	12.9	12.2	11.0	9.3
	EAR	F	MJ/d	4.7	6.5	9.5	10.4	10.2	9.7	9.0	7.8
proteins	RDA ^f	M	g/d	14	22	36	56	61	59	60	60
	RDA ^f	F	g/d	13	21	37	49	52	50	52	51
	RDA ^f	M	en%	5	5	6	7	8	8	9	11
	RDA ^f	F	en%	5	5	6	8	9	9	10	11
	UL	M/F	en%	20	25	25	25	25	25	25	25
fats	AI	M/F	en%	25-40 person with optimum weight: 20-40; overweight person or person with undesirable weight gains: 20-30/35							
	UL	M/F	en%	40	40 or 30/35, see the AI for fats (above)						
• linoleic acid ^e	AI	M/F	g/[kg.d]	-	-	-	-	-	-	-	-
	AI	M/F	en%	2	2	2	2	2	2	2	2
• alpha-linolenic acid ^e	AI	M/F	g/[kg.d]	-	-	-	-	-	-	-	-
	AI	M/F	en%	1	1	1	1	1	1	1	1
• docosahexaenoic acid ^e	AI	M/F	g/[kg.d]	-	-	-	-	-	-	-	-
• n-3 fatty acids from fish ^e	AI	M/F	g/d	0.15	0.15	0.15	0.15	0.2	0.2	0.2	0.2
				- 0.2	- 0.2	- 0.2	- 0.2				
• arachidonic acid ^e	AI	M/F	g/[kg.d]	-	-	-	-	-	-	-	-
• polyunsaturated fatty acids ^g	UL	M/F	en%	12	12	12	12	12	12	12	12
• monounsaturated and polyunsaturated fatty acids ^{g,h}	AI	M/F	en%	-	person with optimum weight: 8-38; overweight person or person with undesirable weight gains: 8-28/33 ^h						
• saturated fatty acids	AI	M/F	en%	-	a.l.a.p. ⁱ	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.
	UL	M/F	en%	15	10	10	10	10	10	10	10
• <i>trans</i> fatty acids	AI	M/F	en%	-	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.	a.l.a.p.
	UL	M/F	en%	-	1	1	1	1	1	1	1
carbohydrates	AI	M/F	g/[kg.d]	-	-	-	-	-	-	-	-
	RDA ^f	M/F	en%	45	45	45	40	40	40	40	40

^f where a recommended dietary allowance is given, an estimated average requirement was also derived; the latter values, however, are not presented in this table, but can be found in the chapters on the nutrients concerned

^g fatty acids with the *cis* configuration

^h adequate intakes for monounsaturated fatty acids plus polyunsaturated fatty acids are not based on the results of any studies on this group of fatty acids, instead they are calculated on the basis of the dietary reference intakes for fats, saturated fats and *trans* fatty acids

ⁱ a.l.a.p. = as low as possible

- = no value set

General introduction and used concepts

-
- 1.1 Background *17*
 - 1.2 Terminology and definitions *18*
 - 1.2.1 Estimated average requirement *20*
 - 1.2.2 Recommended dietary allowance *20*
 - 1.2.3 Adequate intake *22*
 - 1.2.4 Tolerable upper intake level *22*
 - 1.3 Terminology and definitions in other reports on dietary reference intakes *24*
 - 1.4 Methods for determining the estimated average requirement or adequate intake *25*
 - 1.4.1 Incidence of deficiency diseases *25*
 - 1.4.2 Risk of developing chronic diseases *26*
 - 1.4.3 Biochemical parameters of nutritional status *27*
 - 1.4.4 Factorial method *27*
 - 1.4.5 Average intake *28*
 - 1.4.6 Interpolation *29*
 - 1.5 Factors that affect requirement *30*
 - 1.5.1 Dietary factors *31*
 - 1.5.2 Other factors *31*
 - 1.6 Age groups and categories *32*
-

1.6.1	All age groups up to 18 years	32
1.6.2	Age groups above 19 years of age	33
<hr/>		
1.7	Applications	34
1.7.1	Planning food supplies for groups of healthy individuals	35
1.7.2	Drawing up dietary guidelines for healthy individuals	35
1.7.3	Evaluating the consumption figures of groups of healthy individuals	35
1.7.4	Evaluating the intake of individuals who have been shown to have a poor nutritional status	36
1.7.5	Drawing up Guidelines for a healthy diet	36
1.7.6	Applications for which the dietary reference intakes are not intended	36
<hr/>		
1.8	Structure of this document	37
<hr/>		
	References	37

Used concepts

Estimated average requirement

level of intake that, given a normal distribution of requirement, is sufficient for half of a population.

Recommended dietary allowance

level of intake that is sufficient for virtually the entire population, based on the estimated average requirement

Adequate intake

level of intake that is sufficient for virtually the entire population, based on data other than the estimated average requirement.

Tolerable upper intake level

level of intake above which there is a risk that adverse effects will occur.

1.1 Background

In the Netherlands, the first recommendations regarding appropriate intake levels for energy and nutrients were published in 1949. They were drawn up by the Food and Agricultural Policy Committee of the former Ministry of Agriculture, Fisheries and Food. Until 1959, this committee was responsible for producing recommendations. It published various revisions and supplements.

In 1959, the committee's work was taken over by the Committee on Dietary Reference Intakes of the Food and Nutrition Council. The committee, whose composition changed over the course of time, regularly checked its recommendations against the scientific knowledge, adjusting or supplementing them where necessary. Accordingly, the 1989 report entitled Dietary Reference Intakes in the Netherlands was drawn up on the basis of the scientific literature published up to 1987. A second edition, which was published in 1992, updated the information on several nutrients with data from the period 1987-1991.

In 1995, the Food and Nutrition Council organized an international workshop on dietary reference intakes. The results of scientific research increasingly showed that various factors were involved in the development of chronic diseases. One of these factors was the intake of certain nutrients. Examples of these nutrients are calcium and vitamin D, which are now thought to affect the development of osteoporosis and bone fractures. On the basis of this development and other considerations, it was concluded that a review of contemporary dietary reference intakes was needed. When the Food and Nutrition Council was abolished in 1996, its activities (including the review of dietary reference intakes) were taken over by the Health Council.

For the purposes of this review of dietary reference intakes, the President of the Health Council established the Committee on Dietary Reference Intakes, hereafter referred to as ‘the Committee’ (annex A). The Committee will be setting out its findings in the form of a series of recommendations. The first recommendation in this series concerns the dietary reference intakes for calcium, vitamin D, thiamin, riboflavin, niacin, pantothenic acid and biotin. That recommendation was published in July 2000. The present recommendation concerns the dietary reference intakes for energy and for energy-supplying nutrients such as proteins, fats and digestible carbohydrates (macronutrients). It was prepared by one of the Committee's working groups (annex A).

Provided that the intake of energy remains the same, changes in the intake of a macronutrient are, by definition, associated with changes in the intake of at least one other macronutrient*. This hampers the interpretation of research data and results in a relationship between the dietary reference intakes for energy and the macronutrients. For this reason, dietary reference intakes for macronutrients are often formulated in terms of the percentage of total energy intake and this is the nutrient's contribution to the total energy intake. The Committee recommends that, when using dietary reference intakes, the energy percentages of protein, fats and digestible carbohydrates of people who habitually consume alcohol should be calculated on the basis of the total energy intake (i.e. including the energy gained from the consumption of alcoholic beverages).

1.2 Terminology and definitions

The term ‘dietary reference intakes’ is a collective term for the following reference values for energy and nutrients:

- estimated average requirement
- recommended dietary allowance
- adequate intake
- tolerable upper intake level

Figure 1.1 indicates how the dietary reference intakes are derived. Both recommended dietary allowance and adequate intake are quantified values of the intake levels that the Committee considers necessary for health reasons. These quantities are, however, derived by different means (see sections 1.2.2 and 1.2.3).

* Macronutrients, or energy-supplying nutrients, are proteins, fats and carbohydrates. Alcohol is also a source of energy. Since the body has no physiological requirement for alcohol, however, this substance has not been included in this recommendation.

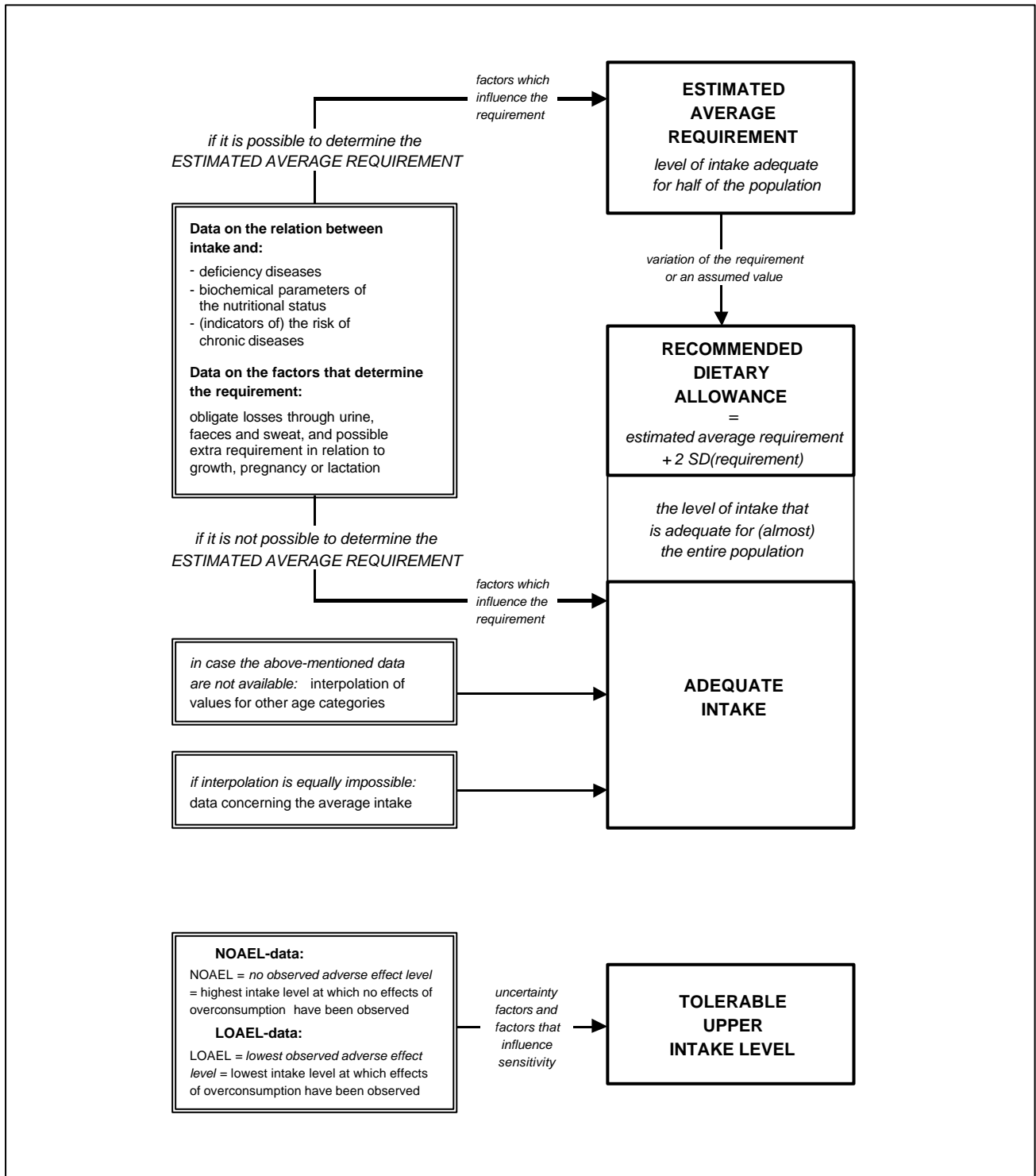


Figure 1.1 Diagrammatic illustration of the means by which dietary reference intakes are obtained (see sections 1.2, 1.4 and 1.5).

1.2.1 *Estimated average requirement*

If a population's requirement for a given nutrient has a normal distribution, then when intake is equivalent to the estimated average requirement 50% of the individuals will have sufficient and the remaining 50% will not (figure 1.2). The estimated average requirement can be determined if the research data describe a dose-effect relationship between intake and requirement that lies in the area of intake around this estimated average requirement. In many cases, however, such data are not available. The Committee remarks that in case of a non-normal distribution it would be more correct to use the median requirement instead of the average requirement.

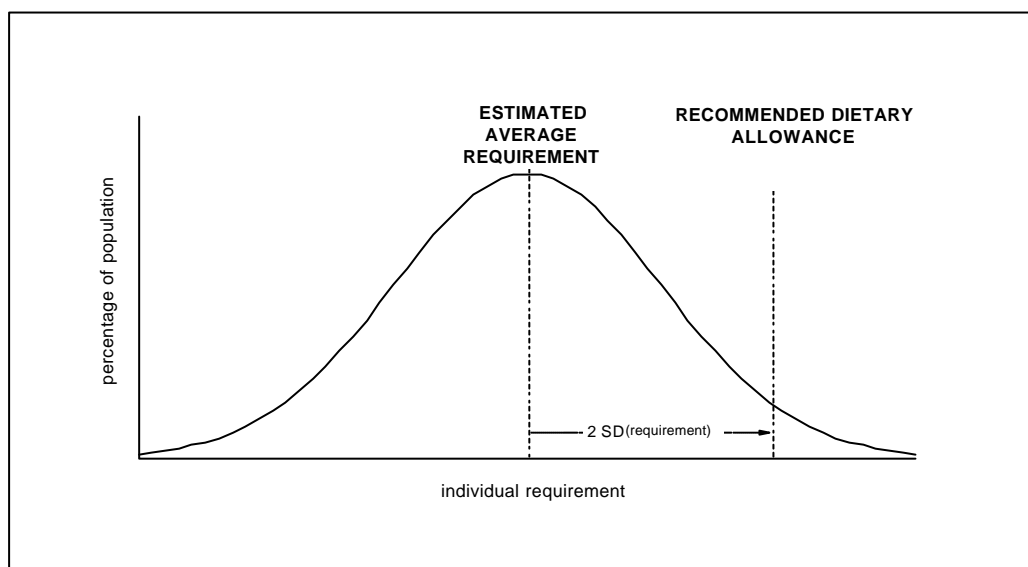


Figure 1.2 Estimated average requirement and recommended dietary allowance, if the requirement has a normal distribution.

1.2.2 *Recommended dietary allowance*

It is only possible to determine a recommended dietary allowance if sufficient data is available to determine the estimated average requirement (figures 1.1 and 1.2).

If the inter-individual variation in requirement is known

If the requirement has a normal distribution (see figure 1.2) and the inter-individual variation for the requirement is known, then the Committee calculates a recommended dietary allowance on the basis of the estimated average requirement plus twice its

standard deviation. This will meet the requirements of 97.5% of the individuals in a population.

If the inter-individual variation in requirement is unknown

Data on inter-individual variation in requirement are often unavailable, inadequate or inconsistent. The Committee makes an assumption, based on several nutrients for which estimates have been made of the coefficients of variation* for requirement:

- Energy: the coefficient of variation for daily energy requirement is estimated to be 20%, on the basis of research using the doubly-labelled water method (Bla96, Bra98, Bru98, Dav97).
- Vitamin A^{**}: the intake of vitamin A that corresponds to a normal electroretinogram has a standard deviation of 300 to 600 mg/d (Sau74). On this basis, the Committee estimates the coefficient of variation for vitamin A requirement to be 15 to 20%.
- Niacin: estimates of the coefficient of variation for the intake of nicotinic acid vary from 8% to 41% (Gol52, Gol55, Hor56, Jac89). These are based on a level of N'-methylnicotinamine excretion via the urine of 1 mg/day (the criterion for determining niacin requirement).
- Vitamin C^{**}: the vitamin C requirement has an coefficient of variation that has been estimated at 23% (Kal97).
- Protein: the coefficient of variation for the protein requirement per kilogram of body weight for adults has been estimated at 16% (Dew96, FAO85); the Committee bases its assumption on a higher coefficient of variation for protein requirement in grams per day.

It is likely that part of the estimated variation will be due to flaws in the measurement methods used. For this reason, actual inter-individual variation is probably smaller than the values stated above. With regard to the protein requirement, the Committee bases its assumption on inter-individual variation rather than on total variation. Inter-individual variation for the protein requirement (in grams per kilogram per day) for babies at birth and up to one year of age is estimated at 12.5%. For individuals above one year of age, the value is 15% (Dew96, FAO85).

Taking the above into account, the Committee uses a coefficient of variation of 10% to 20% for nutrients with an unknown requirement variation. The selected option is explained in each chapter. Dependent on the option selected, the recommended dietary allowance is set at 1.2 to 1.4 times the estimated average requirement.

* Coefficient of variation = 100% x standard deviation / average.

** Here the Committee is anticipating the treatment of this nutrient in a later recommendation.

1.2.3 *Adequate intake*

In the case of many nutrients there is too little research data to be able to identify the level of intake that is sufficient for exactly 50% of a given group. In other words, the average requirement is unknown. Similarly, it is not possible to determine the recommended dietary allowance, since this is derived from the estimated average requirement. In such cases, a direct estimate is made of the level of consumption that appears to be sufficient for virtually the entire population, namely adequate intake. Adequate intake will often be higher than the recommended dietary allowance (in those cases where it would have been possible to establish the latter quantity).

The practical significance of adequate intake is the same as that of a recommended dietary allowance, both describe the level of intake that the Committee considers necessary for health reasons. The terminological distinction relates to a difference in the way in which these values are derived (figure 1.2) and to the resultant difference in the 'firmness' of the value (figure 1.3).

1.2.4 *Tolerable upper intake level*

As with other chemical substances, a high nutrient intake can produce adverse effects. For this reason, the Committee determines the highest intake level at which, according to currently available data, no harmful effects have been observed or would be expected to occur. This so-called tolerable upper intake level is always higher than the ideal intake level (figure 1.3). The Committee emphasizes that this upper limit is not the ideal intake level, that is the recommended dietary allowance or adequate intake.

Derivation of the tolerable upper intake level

The tolerable upper intake level is based on the highest intake level in humans at which no adverse effects have been observed (no adverse effects level or NOAEL), or on the lowest intake level at which adverse effects have been observed in humans (lowest observed adverse effect level or LOAEL; figure 1.3; IOM97).

In the ideal situation, the tolerable upper intake level is based (analogously to the determination of the recommended dietary allowance) on the statistical distribution of individual NOAELs or LOAELs. However, detailed data of this kind is almost never available. Available descriptions of the adverse effects of high intake levels in humans usually derive from observational research in groups or in individuals. Intervention studies into the toxic effects of nutrients in humans are ethically unacceptable. Given the limited availability of information on NOAELs and LOAELs, uncertainty factors are

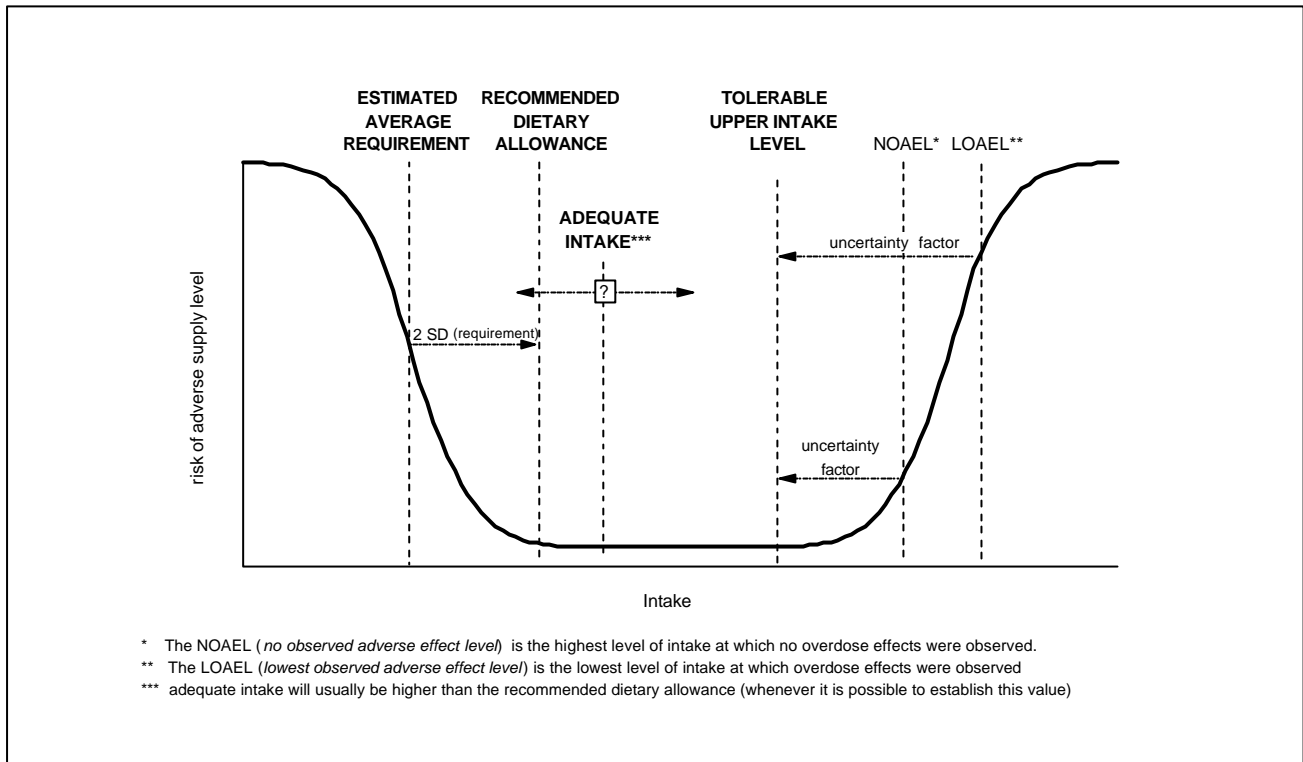


Figure 1.3 Relationship between individual intake and the risk of adverse supply level.

used when deriving a value for the tolerable upper intake level (figure 1.3). The stronger the research evidence concerning the LOAEL or NOAEL, the smaller the uncertainty factor used by the Committee. The uncertainty factors used for NOAELs are usually smaller than those used for LOAELs. Large uncertainty factors are used where the research results relate to the effects of an acute body burden rather than a chronic body burden, or where the nutrient in question is one that is only excreted slowly from the body.

In most cases, the tolerable upper intake level coincides with the total intake of a nutrient. There may occasionally be reasons for deviating from this approach, for example if there are indications that the mode of intake of a specific nutrient (via food or via supplements, such as calcium and magnesium) or its chemical form (for example, folic acid) can affect the safety of higher doses. For the purpose of illustration, where food is supplemented or enriched with folic acid, the form of the vitamin used is one that does not naturally occur in food. All reported cases of adverse effects associated with a high level of folic acid intake have involved the use of supplements and enriched foods.

Tolerable upper intake level for young age groups

The Committee presumes that babies of up to one year of age are more sensitive to high intake levels than are older individuals. The reason for this is that, in young children, the organs that are primarily involved in rendering toxic substances harmless are less capable of performing this task than they are in older individuals.

Data regarding the sensitivity of children aged from 1 to 9 is usually insufficient to allow a tolerable upper intake level to be derived. From one year of age onwards, the most important organs involved in detoxification (liver and kidneys) function almost as effectively as in adult individuals. For this reason, the Committee usually fixes the tolerable upper intake level for children aged one year and above at the same level that is used for adults. However, there is sometimes cause to adjust the value in proportion to the reference weight of the age group in question.

1.3 Terminology and definitions in other reports on dietary reference intake

The terminology and definitions in the present recommendation coincide with those of the new USA Dietary reference intakes (IOM97, IOM98). The distinction between the recommended dietary allowance and adequate intake (sections 1.2.2 and 1.2.3) implies that another approach is being taken than that outlined in the 1989 report on Dutch dietary reference intakes. Some changes have also been made to the terminology. In the previous set of Dutch dietary reference intakes, the term 'average minimum requirement' was used instead of 'estimated average requirement' (VR92). The Committee has opted for conformity with the terminology used in the new USA dietary reference intakes rather than retention of the Dutch definitions and terms from 1992.

At the international level there are considerable differences in the terminology and definitions used. Scandinavian dietary reference intakes (NM96) do not distinguish between 'recommended' and 'adequate'. Instead they use the term 'recommended intake' for all recommended dietary allowances and adequate intakes. However, the dietary reference intakes of the European Union (EC92) and Great Britain (UK91) do distinguish between 'recommended' and 'adequate', as do those of Germany, Switzerland and Austria (DGE00). However, the definitions used in these foreign reports do not fully coincide with those used in the present recommendation.

Table 1.1 Comparison of the terminology in the present recommendation and that in the American Dietary reference intakes, and several other reports on dietary reference intakes.

<i>the present recommendation</i>	estimated average requirement	recommended dietary allowance	adequate intake	tolerable upper intake level
<i>IOM97, IOM98 (United States)</i>	estimated average requirement	recommended dietary allowance	adequate intake	tolerable upper intake level
<i>VR92 (the Netherlands)</i>	average minimum requirement	recommended dietary allowance and adequate intake	recommended dietary allowance and adequate intake	-
<i>EC92 (European Community)</i>	average requirement	reference intake population	tolerable intake level	-
<i>UK91 (Great Britain)</i>	estimated average requirement	reference nutrient intake	safe intakes	-
<i>DGE00 (Germany, Switzerland, Austria)</i>	-	empfohlene Zufuhr	Schätzwerte	-
<i>NM96 (Scandinavia)</i>	average requirement	recommended intake	recommended intake	upper limit of intake

Table 1.1 shows a summary of the terms used in the present recommendation, the terminology of the latest USA Dietary reference intakes (which coincides with the terms used in this recommendation), the terminology used in the last Dutch recommendation and the above-mentioned European publications in this field.

1.4 Methods for determining the estimated average requirement or adequate intake

There are a variety of methods that can be used to derive estimated average requirement or average intake. These methods will be explained in the present section.

1.4.1 Incidence of deficiency diseases

It is ethically unacceptable to induce deficiency diseases in human subjects. For this reason, there is little data concerning the level of intake at which symptoms of deficiency start to occur. Accordingly, the dietary reference intakes are usually not based on this type of data. The Committee assumes that dietary reference intakes derived from the other approaches (sections 1.4.2 to 1.4.6) are more than sufficient to prevent deficiency symptoms.

1.4.2 *Risk of developing chronic diseases*

For some nutrients there is convincing evidence that their use affects the risk of developing certain chronic diseases. Data on this can relate to the occurrence of the disease itself, or to the level of ‘intermediate end points’, which very likely affect the development of the disease. It is partly on the basis of data such as this that the Committee established the dietary reference intakes.

The Committee evaluates research results that indicate a possible causal relationship between the intake of the nutrient and the occurrence of chronic diseases. In doing so, it takes note of the type of research which produced the results (table 1.2), the strength of the relationship that has been identified, the lack of ambiguity in the research results and the presence or absence of a dose-effect relationship.

The Committee considers that the most reliable results are those obtained from intervention studies or prospective cohort studies (the first two types of studies listed in table 1.2). Accordingly, it primarily uses results of this type to derive dietary reference intakes for the prevention of chronic disease. The results of research of the third, fourth and fifth types (table 1.2) have a primarily supportive value. In the case of some nutrients or population groups, the only data available is that which is derived from the latter three types of research. In those cases, the Committee does not base the dietary reference intakes on the relationship with chronic disease.

Where dietary reference intakes are based on the risk of developing a chronic disease, the Committee will generally determine an adequate intake rather than a recommended dietary allowance. The reason for this is that information from intervention studies and prospective cohort studies is generally inadequate for the purposes of quantifying the estimated average requirement. Intervention studies generally only describe a few levels of intake. The conclusions arising from prospective research do not usually relate to specific levels of intake, but rather to thirds, quarters or fifths of the intake.

In this recommendation, the Committee will restrict its considerations to the influence of the nutrients. There are often other factors that influence the development of the chronic disease in question.

Table 1.2 Types of study, in order of decreasing strength of evidence.

intervention studies in human subjects, with disease or death as the yardstick for results

intervention studies in human subjects, with intermediate end points or risk factors as the yardstick for results; prospective cohort studies

controlled studies of patients; migrant studies^a

ecological studies^b; descriptions of individual patients, experimental animal research

in vitro research

^a In migrant studies, disease and death in the first and second generation of migrants are compared. The dietary practices of the first generation usually show marked similarities with those of their country of origin, while those of the second generation more closely resemble the dietary habits of the destination country.

^b Ecological analyses usually involve comparisons (also involving observation) between countries or regions. These are not based on observations of individuals but on population averages.

1.4.3 *Biochemical parameters of nutritional status*

In the case of some biochemical parameters, it is true to say that whether or not a given threshold value is achieved is an indication of an inadequate intake of the nutrient in question. In that case, the relationship between the intake of the nutrient and this biochemical variable can be used as a basis for estimating the estimated average requirement or adequate intake. The average intake at which the biochemical variable reaches the threshold value is the estimated average requirement. If this level of intake cannot be determined, due to a paucity of data, then efforts are made to identify a level of intake above which, in virtually all individuals, the biochemical variable has a higher value than the threshold value. This level of intake is designated adequate intake.

In the case of some nutrients, there are various biochemical variables that characterize nutritional status. The combination of variables used is one of the factors that determines the level of the dietary reference intakes. In selecting a given dietary reference intake, the Committee is guided by considerations such as the anticipated health benefits.

1.4.4 *Factorial method*

The factorial method involves adding up the various factors that determine the requirement (figure 1.4). This relates to the amounts of nutrients that leave the body via the faeces, urine and skin. It also concerns the amounts that, where appropriate, are required for growth, pregnancy or lactation. The extra requirement during growth and pregnancy is due to the amounts of nutrients that become incorporated into newly formed tissues, an effect which is referred to as 'retention'. The extra requirement

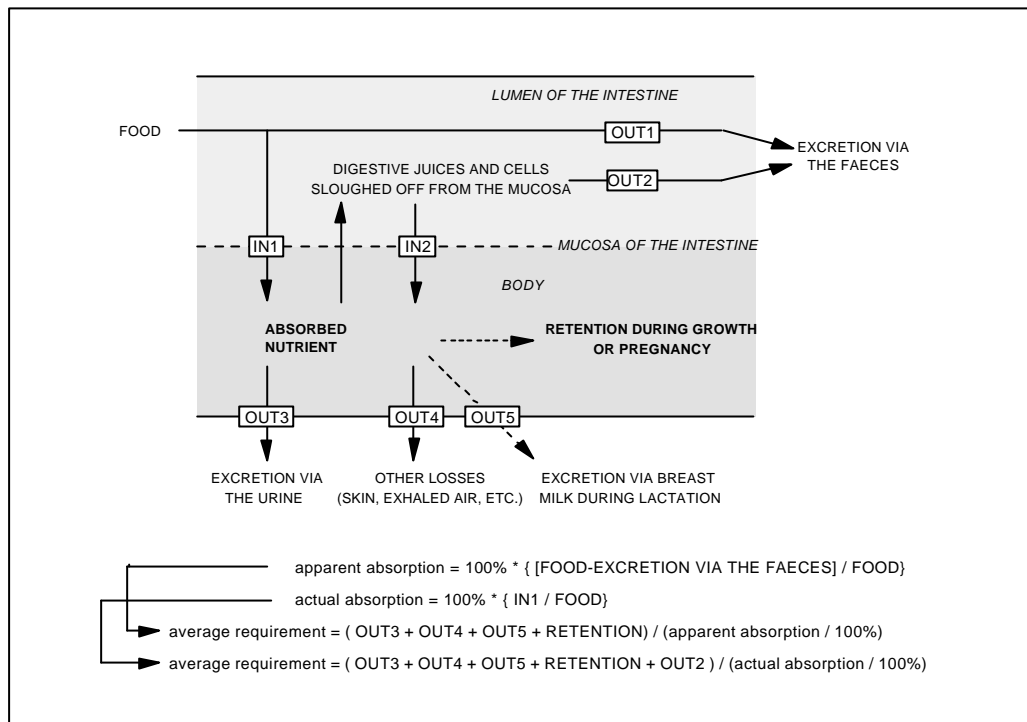


Figure 1.4 Estimation of average requirement using the factorial method.

during lactation, is equivalent to the amounts of nutrients lost to the body in the form of human milk.

The apparent absorption percentage is the difference between intake and excretion via the faeces, divided by intake. This is an underestimation of the fraction that is actually absorbed, since not all of the nutrients contained in faeces originate directly from the food. Some are derived from the digestive juices, while others originate from cells sloughed off from the lining of the intestine. Using isotope techniques it is now possible to determine the actual absorption percentage. Although this type of data is preferable to estimates of apparent absorption, it is not always available.

1.4.5 Average intake

Age group from birth to five months

Study results that determine the intake and nutritional status of babies up to the age of five months are generally not available. The Committee assumes that human milk is the best form of nutrition for this age group. For this reason, it has selected an adequate intake value that is equal to the average intake of infants who receive no other food

than human milk*. In this connection, they assume that such infants consume an average of 0.8 litres of human milk per day or 0.15 litres per kilogram per day (All91, But84, Hei93). They also assume that the human milk in question contains the average concentration of nutrients found in human milk**.

In the case of some nutrients, the mother's intake determines the composition of her breast milk. In the case of these nutrients, the Committee uses the concentration that is achieved at the usual level of intake in the Netherlands.

Adequate intake for formula-fed infants is sometimes higher than that associated with lactation, since the bioavailability of some nutrients in infant formulas is less than that in human milk.

Adults

In the case of some nutrients, too little is known about them to enable dietary reference intakes to be derived using any of the above-mentioned methods. Where there are no reports concerning deficiency symptoms for micronutrients occurring in the Netherlands, the Committee sets the adequate intake for adults at the same level as average intake.

1.4.6 *Interpolation*

In the case of some nutrients there is no data regarding the younger age groups. In such cases, the Committee has opted for the following approach (after studying the procedure recently adopted in the United States for determining the dietary reference intakes for B vitamins; IOM98): they determine adequate consumption by means of interpolation between adequate intake for infants aged up to five months, and the recommended dietary allowance or adequate intake for adults. In this connection, they assume that:

- based on the median age of the individual age groups, for those age groups up to 18 years of age there is a linear relationship between increasing requirement and increasing age,
- the requirement for the 14 to 18 age group is equal to that of those aged from 19 to 50.

* For vitamins D and K, the average intake via human milk is inadequate. For babies fed human milk supplementation with these vitamins is therefore recommended and generally accepted.

** This relates to the composition of human milk in mothers with a good nutritional status. No allowance is made for the fact that, during the first few days after birth, human milk has a different composition (colostrum) from human milk produced at a later stage.

Adequate intake is calculated as follows:

$$AI = AI_{[0-5 \text{ month}]} + \left(LF \times \left[\left(AI_{[>14 \text{ year}]} \text{ or } AH_{[>14 \text{ year}]} \right) - AI_{0-5 \text{ month}} \right] \right)$$

In this formula, 'AI' stands for adequate intake and 'RDA' for recommended dietary allowance. 'AF' is the age factor. This has the following values: 0.00 for the age group from birth to five months, 0.03 for the 6 to 11 month age group, 0.14 for the group aged from 1 to 3; 0.38 for those aged from 4 to 8, 0.69 for the 9 to 13 age group and 1.00 for the 14 to 18 age group.

1.5 Factors that affect requirement

Where different countries adopt different dietary reference intakes, this is generally due to differing interpretations of the available knowledge or to differences in basic assumptions and definitions. However, it is also possible that the populations of different countries genuinely have different requirements. These can be associated with dietary patterns and individual characteristics such as ethnicity, as well as with differences in lifestyle and environmental factors. Within countries, the same factors can also lead to differences in requirement between subgroups.

Certain subgroups of the population may also have differing sensitivities to overdosing on certain nutrients. In this way, some individuals have a genetic predisposition to elevated iron absorption. As a result, at relatively low intake levels, this can produce harmful effects associated with overconsumption.

Within the population there are also groups with a normal nutrient requirement that, if their dietary pattern is abnormal, experience a relatively high incidence of low intake for certain nutrients. When deriving values for dietary reference intakes, however, the main emphasis is placed on the amount required rather than the amount used. As a result, the identification of the above groups is not a factor in determining these values. However, this is one of the areas in which dietary reference intakes are used (1.7.3).

Dietary reference intakes relate to the requirement and sensitivity of the majority of the population of the Netherlands. In deriving dietary reference intakes, the Committee based their calculations on an average Western dietary pattern, a healthy lifestyle and the most common individual characteristics encountered in the Netherlands. Where appropriate, the Committee indicates where the requirement for specific groups has been increased. Accordingly, for vitamin D intake per age group, two adequate intakes are defined – one for individuals with endogenous vitamin D production and one for those without.

1.5.1 *Dietary factors*

Dietary pattern can affect the nutrient requirement via the bioavailability of the nutrient and the degree to which precursors* can meet the requirement for the nutrient in question.

Bioavailability

The dietary reference intakes are attuned to the average bioavailability of nutrients in the Western diet. In food science, bioavailability is defined as the fraction of intake that is available for normal physiological functions (for precursors this is the conversion to an active form) or for storage (Jac97).

Bioavailability is determined by the structure and chemical form of the nutrient (for example Fe²⁺ versus Fe³⁺), the amount of the nutrient in the diet, the matrix in which the nutrient is located (for example, carotenoids in vegetables or dissolved in edible oil) and the presence of substances that are involved in absorption. The bioavailability of nutrients can also be affected by nutritional status, genetic factors and intestinal infections.

Bioconversion and the efficacy of precursors

The requirement for certain nutrients can be partly met through the consumption of precursors, which are converted to the nutrient in question inside the body. In this way, the body converts certain carotenoids to vitamin A, and tryptophan to niacin. The extent to which the bioavailable precursor is converted to the active nutrient is referred to as bioconversion (Cas98). The processes of bioavailability and bioconversion are collectively referred to as 'efficacy'.

1.5.2 *Other factors*

In addition to dietary factors, factors peculiar to individuals such as lifestyle and environmental factors can also have an effect on requirement. In this way, skin colour and exposure to sunlight affect the requirement for vitamin D. Body weight and physical activity affect the requirement for energy. Smoking habits affect the requirement for vitamin C, and the need to fight off infection affects the requirement for

* Precursors are substances from which the body can produce the nutrient in question. Thus β-carotene is a precursor of vitamin A.

Table 1.3 Category/age-group classification with reference weights and heights.^a

age group / category	reference weight, kg		reference height, cm	
	M	F	M	F
from birth to five months	6	5.5	61	59
6 to 11 months	9	8.5	73	71
1 to 3 years of age	14	13.5	93	92
4 to 8 years of age	24	23.5	123	122
9 to 13 years of age	40	41	152	152
14 to 18 years of age	65	59	178	169
19 to 30 years of age	75	64	182	168
31 to 50 years of age	72	62	179	166
51 to 70 years of age	74	64	176	163
Age 71 and above	74	63	172	159
pregnancy	-	68	-	167
lactation	-	64	-	167

^a M = boys and men; F = girls and women

vitamin A. Genetic factors and risk factors for chronic diseases can also affect requirement.

1.6 Age groups and categories

The Committee specifies dietary reference intakes according to age and sex, and sets separate dietary reference intakes for pregnancy and lactation. When drawing up age group categories, the Committee adopted those used in the latest USA Dietary reference intakes (IOM97, IOM98). For this reason, the group classification used in the present recommendation does not comply fully with that used in the 1989 report on Dutch dietary reference intakes (VR92).

Table 1.3 shows the group classification used in the present recommendation, and the reference values for height and weight.

1.6.1 All age groups up to 18 years of age

The reference values for height and weight for the age groups up to 18 years of age (table 1.3) and for the increases in height and weight within these groups (table 1.4) were derived from the results of a large-scale growth study. This study used a random sample of 14,500 Dutch infants, young children and adolescents that was representative of the Dutch population as a whole (Fre98, Fre00a, Fre00b, TNO98).

Table 1.4 Average growth in weight and height for the age groups up to 18 years of age.^a

age group / category	growth in weight, g/day		growth in height mm/day	
	M	F	M	F
from birth to five months ^b	23.6	21.7	0.9	0.84
six to eleven months	12.8	12.1	0.47	0.48
1 to 3 years of age	6.6	6.7	0.27	0.27
4 to 8 years of age	7.3	7.7	0.18	0.18
9 to 13 years of age	12.1	11.9	0.16	0.15
14 to 18 years of age	10.5	5.2	0.08	0.03

^a M = boys and men; F = girls and women

^b There are no data for the first two weeks of life.

The rate of growth is extremely rapid during the first six months. Although consumption of human milk and infant formulas is increasing in absolute terms, the intake per kilogram of body weight has remained more or less constant. For this reason, the dietary reference intakes for this age group (in contrast to those for the other groups) are represented as the amount per kilogram of body weight per day.

1.6.2 Age groups above 19 years of age

The average height for the age groups 19 to 30 years of age and 31 to 50 years of age are based on data collected in the period from 1993 to 1997, using representative random sampling tests. The populations sampled were those of Amsterdam, Doetinchem and Maastricht. The measurements were based on a sample of 3,984 individuals in the first of these two age groups and 12,179 individuals in the second (Smi94). For the age groups 51 to 70 years of age and >70 years of age, these values are based on representative random sampling tests carried out on the population of Rotterdam. The measurements were based on a sample of 3,899 individuals in the first of these two age groups and 3,023 in the second (Hof95). The fact that the reference height in elderly individuals is less than that in young people is largely due to a cohort effect. There is also an age effect, since it has been estimated that elderly individuals lose one to two centimetres of height per decade (Dey99, WHO95a).

The reference values for body weight in age groups above 18 years of age are calculated on the basis of the average height and an optimal Quetelet Index. The Quetelet Index is the weight in kilograms divided by the square of the height in metres. The Committee has set the ideal Quetelet Index for individuals aged 18 to 50 at 22.5 kg/m², for those aged 51 to 70 it is 24 kg/m² and for individuals aged 71 and above it is 25.0 kg/m² (Tro96, WHO95b).

1.7 Applications

The dietary reference intakes are intended for healthy individuals. Their primary purpose is the prevention of disease. They are used for:

- planning food supplies for groups of healthy individuals
- drawing up nutritional guidelines for healthy individuals
- evaluating the consumption figures of groups of healthy individuals
- evaluating the intake of individuals who have been shown to have a poor nutritional status
- Guidelines for a healthy diet

Table 1.5 Summary of applications and corresponding types of dietary reference intakes.

application	type of dietary reference intakes		
	estimated average requirement and variation in requirement	recommended dietary allowance or adequate intake	tolerable upper intake limit
dietary planning for groups of healthy individuals		+	+
drawing up dietary guidelines for healthy individuals		+ ^a	+
evaluating the consumption figures of groups of healthy individuals	+		+
evaluating the intake of individuals whose poor nutritional status has been established using biochemical parameters	+ ^a	+ ^a	+
drawing up guidelines for a healthy diet		+	+

^a Here it is possible to take into account dietary factors, individual characteristics and lifestyle factors that affect requirement.

As explained in section 1.2, the term ‘dietary reference intakes’ is a collective term for various reference values for energy and nutrients. The recommended dietary allowances have the same practical significance as the values for adequate intake since both indicate a level of intake that is considered necessary for health reasons. When evaluating the consumption figures for groups of healthy individuals, the estimated average requirement should be used instead of the recommended dietary allowance or adequate intake. The tolerable upper intake level is considered appropriate for all of the applications described here. Table 1.5 and the rest of this section show which type of dietary reference intake is appropriate for which application.

1.7.1 *Planning food supplies for groups of healthy individuals*

When planning food supplies for groups of healthy individuals, the recommended dietary allowances and adequate intake levels should be used. This application is intended for organizations that provide meals, such as prisons, boarding schools and barracks. If the diet contains the recommended dietary allowances and adequate intake levels for the various nutrients, then this will meet the requirements of virtually all individuals.

1.7.2 *Drawing up dietary guidelines for healthy individuals*

Recommended dietary allowances and adequate intakes are also used when drawing up guidelines for a healthy diet for individuals. When used at the level of the individual, these guidelines can (if appropriate) be geared to dietary factors and other factors that affect requirement (1.5).

1.7.3 *Evaluating the consumption figures of groups of healthy individuals*

If the average values and the variations of a group's intake and requirement are known then it is possible to estimate how many individuals have an inadequate intake (see section 1.5.3 in VR92). Annex C contains intake estimates of the intakes of several of the nutrients that are dealt with in the current recommendation. Data of this kind does not make it possible to detect individuals with inadequate diets. However, this can be done by determining nutritional status at the level of the individual (see also section 1.7.4).

Purely on the basis of recommended dietary allowances or adequate intakes it is not possible to estimate the percentage of individuals with inadequate levels of intake. Where the Committee has derived a recommended dietary allowance, however, the estimated average requirement and the variation of the requirement are available (see section 1.2.2). On the basis of these data it is possible to estimate the percentage of individuals with insufficient levels of intake.

In those instances where the Committee derives an adequate intake, the estimated average requirement is, by definition, unknown (see 1.2.3). For these nutrients it is only possible to make a rough evaluation of the consumption figures. One such example is the situation in which average intake is equal to adequate intake. Half of the people concerned have an intake which is less than the adequate intake, but only in a part (of unknown size) of this group will the intake be inadequate.

1.7.4 *Evaluating the intake of individuals who have been shown to have a poor nutritional status*

The level of a given biochemical parameter will sometimes indicate whether or not an individual has a deficiency of a given nutrient. By comparing his or her intake with the estimated average requirement and recommended dietary allowance (or adequate intake) it is possible to determine whether this has been caused by excessively low levels of intake. It is true to say that the further the intake lies beneath the estimated average requirement, recommended dietary allowance or adequate intake, the greater the risk that this will be inadequate (figure 1.3).

In the absence of individual information on parameters of nutritional status, dietary reference intakes provide insufficient information to be able to evaluate the consumption figures of individuals. If an individual's intake is less than the recommended dietary allowance or adequate intake, then there is a risk that his or her requirement will not be met (figure 1.3). Thus status parameters are needed in order to check whether or not intake is adequate.

1.7.5 *Drawing up Guidelines for a healthy diet*

In 1986, the Food and Nutrition Council described the changes in dietary pattern in the Netherlands that were required in order to prevent both deficiency and chronic diseases. These were the so-called Guidelines for a healthy diet (VR86). In this recommendation, the requisite intake levels were derived and compared with Dutch data on food consumption and nutritional status.

The last Dutch recommendation on dietary reference intakes was primarily aimed at the prevention of deficiency diseases (VR92). The present recommendation focuses on the prevention of both deficiency diseases and chronic diseases, but it does not include a description of any necessary changes in current Dutch dietary patterns.

1.7.6 *Applications for which the dietary reference intakes are not intended*

The requirement for nutrients can change as a consequence of an illness, recovery from illness or while slimming. Dietary reference intakes may therefore not be applicable in such situations. Dietary reference intakes for healthy individuals can nevertheless be used as a starting point when drawing up recommendations for groups of patients (Tam97).

Nutrition labelling on foodstuffs

In the Netherlands, the reference values for nutrition labelling on foodstuffs are governed by the Commodities Act. These values are based on European labelling regulations rather than on Dutch dietary reference intakes. The Commodities Act Decree of 20 April 1993, which is currently in force, is based on a European Directive dating from 1990.

1.8 Structure of this document

Each nutrient to be discussed has its own chapter, and each of these chapters has the following structure:

- An introductory section is used to discuss the nomenclature and the properties of the nutrient in question. It also covers the nutrient's physiological significance, the symptoms of deficiency and the possible involvement of deficiency in the development of chronic diseases.
- In the second section, the Committee identifies the factors that influence requirement.
- The third section covers the derivation of the estimated average requirement and recommended dietary allowance or adequate intake. The Committee provides an explanation of the way in which the requirement was estimated. It goes on to describe, for each category of the population, the scientific data upon which it based the dietary reference intakes in question.
- In the fourth section, the Committee derives the tolerable upper intake levels.
- The fifth section contains a broad comparison with previous Dutch dietary reference intakes and with those used in other countries.

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Energy

Summary 43

2.1 Introduction 44

2.1.1 Energy-providing nutrients 44

2.1.2 Physiological significance 45

2.2 Factors that affect energy requirement 46

2.2.1 Dietary factors 46

2.2.2 Other factors 47

2.3 Estimated average requirement 49

2.3.1 Derivation method 49

2.3.2 Age groups from birth to 11 months 53

2.3.3 Age groups from 1 to 18 years of age 54

2.3.4 Age group above 18 years of age 55

2.3.5 Pregnancy 56

2.3.6 Lactation 58

2.4 Comparison with other reports on dietary reference intakes 59

References 59

Summary

Table 2.1 Summary of the estimated average requirements for energy derived in this section.

group	method	estimated average requirement (MJ/d ^a)	
		boys/men	girls/women
0 to 2 mths	² H ₂ ¹⁸ O method + accretion	0.39 MJ/[kg.d] (1.8 MJ/d)	0.39 MJ/[kg.d] (1.8 MJ/d)
3 to 5 mths	”	0.35 MJ/[kg.d] (2.4 MJ/d)	0.35 MJ/[kg.d] (2.4 MJ/d)
6 to 11 mths	”	3.0	3.0
1 to 3 years of age	”	5.0	4.7
4 to 8 years of age	”	7.2	6.5
9 to 13 years of age	”	10.6	9.5
14 to 18 years of age	”	14.0	10.4
19 to 30 years of age	basal metabolic rate ^b x PAL ^c	12.9	10.2
31 to 50 years of age	”	12.2	9.7
51 to 70 years of age	”	11.0	9.0
> 70 years of age	”	9.3	7.8
pregnancy	factorial - and ² H ₂ ¹⁸ O method	-	+ 1.2 ^d
lactation	factorial method	-	+ 2.1 ^e

^a unless a unit is indicated

^b Calculated using predictive formulas based on the reference weight.

^c Derived on the basis of research results using the ²H₂¹⁸O method. The Committee has based its calculations of the estimated average requirement for individuals aged 19 and above on the PAL values associated with the average low physical activity level that is characteristic of Dutch adults. The PAL values associated with the recommended level of physical activity are indicated in section 2.3.4.

^d Based on the usual reduction in physical activity seen in Dutch women during pregnancy.

^e Based on the usual metabolic combustion of 0.5 kg of body fat per month in lactating Dutch women.

2.1 Introduction

2.1.1 *Energy-providing nutrients*

Humans obtain the energy that they require by consuming proteins, fats, carbohydrates and alcohol. Proteins and digestible carbohydrates provide 17 kJ per gram, fats provide 38 kJ per gram and alcohol provides 29 kJ per gram. These values are corrected for losses via the urine and faeces. Sugar alcohols* provide 8-15 kJ per gram, less energy than digestible carbohydrates (VR87). Some types of dietary fibre also provide energy. Thus pectin provides 12 kJ per gram (Sou92). Cellulose provides no energy at all (Sou92). On average, non-digestible carbohydrates in a mixed diet provide approximately 8 kJ per gram.

As stated in the introductory chapter, dietary reference intakes for macronutrients are often expressed as a percentage** of total energy intake (see section 1.1). The sum of the percentages of total energy intake of protein, fats, carbohydrates and (where appropriate) alcohol is, by definition, 100%. In this recommendation, however, the Committee has set a lower total for the recommended dietary allowances or adequate intakes, as the case may be, for proteins, fats and carbohydrates (see table 2.2). This can be made up to 100 percent of total energy intake by increasing the consumption of proteins or carbohydrates to exceed the recommended dietary allowance. In this context, it is important to allow for the tolerable upper intake level for proteins of 25 percent of total energy intake. Furthermore, in practice, part of this gap will be filled by the consumption of alcoholic beverages. According to the 1998 Dutch Food Consumption Survey, Dutch adults obtain 3 to 5 percent of their energy from alcohol.

In the course of conversion processes within the body, about half of the energy value of proteins, fats and carbohydrates is stored in the form of the energy-rich substance adenosine triphosphate (ATP, the primary energy source for all of the processes of life). The remaining energy is released in the form of heat. Although the conversion of dietary fat to body fat and that of glucose to glycogen are efficient processes, 5% of the energy is converted to heat. When glucose is converted to body fat, heat production is approximately 30%. During physical exertion, 80% of the energy value of ATP is lost as heat.

* Sugar alcohols are used as sugar-replacing sweeteners.

** This is the nutrient's contribution to the total energy intake.

Table 2.2 Distribution of energy intake among macronutrients in adults, based on the dietary reference intakes derived in this recommendation.

nutrient	recommended dietary allowance or adequate intake as percentage of total energy intake	
	individuals with a desirable body weight	overweight individuals or those with undesirable weight gains
proteins ^a	10	10
fats	20 to 40	20 to 30 or 35
digestible carbohydrates	40	40
total	70 to 90	70 to 80 or 85
remainder	10 to 30	15 or 20 to 30

^a The recommended dietary allowance of protein for adults varies, dependent on age group and sex, from 8 to 11 percent of total energy intake.

2.1.2 *Physiological significance*

Energy is essential for all of the processes of life, for the maintenance of body tissues and for carrying out physical activities. In addition, children and pregnant women require energy for tissue growth, while women who are breastfeeding an infant require energy for the production of human milk.

The energy requirement has a narrow margin of safety. A chronically inadequate energy intake results in weight loss, while a chronically excessive intake causes individuals to become overweight. The estimated average requirement for energy is therefore suitable for the evaluation of consumption figures at group level, but not at the level of the individual. The energy intake of an individual with an ideal body weight must be equivalent to his or her individual requirement. This deviates to a greater or lesser extent from the estimated average requirement. The coefficient of variation for the energy requirement is estimated at approximately 20% (see section 1.2.2).

The regular measurement of body weight is the simplest way of determining whether energy intake coincides with the individual's requirements. When interpreting this information, account should be taken of other causes of changes in weight, such as growth, pregnancy or changes in muscle mass resulting from a change in the individual's pattern of activity.

2.2 Factors that affect energy requirement

2.2.1 *Dietary factors*

Fat

The effect of the diet's fat content on the energy balance (thus also on the regulation of weight) is described in the chapter on fats (see section 4.7.1). In this section, the Committee concludes that for individuals who are in energy balance, the iso-energetic replacement of fats with carbohydrates has no effect on body weight. If the energy intake exceeds requirement then a diet with a higher fat content would result in a greater increase in weight than would a low-fat diet. Intervention studies, in which food is provided *ad lib*, show that a reduction in the fat content of the diet reduces the risk of excessive energy intake. It is estimated that, on average, a 10% reduction of fat's contribution to total energy intake, results in a reduction in body weight of two to three kilograms. This reduction of body weight is achieved within six months, after which body weight stabilizes at the new level.

Protein and alcohol

Energy consumption increases during the first few hours after eating an energy-providing nutrient (macronutrient). The magnitude of the thermogenesis induced by the nutrient varies from one macronutrient to another. Dietary protein increases energy consumption by approximately 25% of the amount of energy contained in the consumed protein (Jéq95). For alcohol, this value is around 15% (Wes89). The increase in energy consumption as a result of the consumption of carbohydrates and fats is considerably less, making up 8% and 4% respectively of the total energy intake via the nutrient in question (Jéq95). Since there is only a slight difference between carbohydrates and fats, this may explain why the iso-energetic replacement of fats by carbohydrates has no measurable effect on energy consumption and body weight. Proteins are the least efficient energy suppliers. This is consistent with the observation that slimmers can promote weight loss by replacing carbohydrates with protein (Sko99). As has already been stated, alcohol is an inefficient source of energy, but this is of little relevance in terms of public health since high alcohol consumption produces adverse effects.

Meal frequency

On the basis of evidence from observational research, it has been suggested that energy consumption is also affected by meal frequency. However, intervention studies were unable to duplicate this effect (Ver91, Ver93a, Ver93b).

2.2.2 *Other factors*

Body weight and body composition

Body weight is an important determinant of basal metabolic rate*. Energy consumption during physical activity is partly dependent on body weight, especially if those activities involve moving the body (for example, walking and climbing).

Tissues and organs differ markedly in terms of energy consumption. The energy consumption of organs is high while in tissues it is low. Thus the relative contribution of organs, fat tissue and muscle tissue to body weight has an effect on basal metabolic rate. In babies, the brain consumes a relatively large quantity of energy, while in adults it is the liver that has the highest relative energy consumption (FAO85). Also, individuals with a large percentage of body fat require less energy than do other individuals of the same weight but with less body fat. This partly explains the difference between men and women. On average, women have 10% more fat than men of the same weight. This difference between men and women diminishes with increasing age (Sch85).

Physical activity

The level of physical activity has a considerable influence on energy requirement. The PAL value (PAL = physical activity level) defines the level of physical activity. It is the factor by which basal metabolic rate must be multiplied when calculating the 24-hour energy consumption (Jam88). The average PAL value varies from 1.2 in the very inactive, to 2.4 in extremely active individuals. Although higher values (of up to 5) have been measured during periods of extreme activity lasting for several weeks (the Tour de France, Antarctic expeditions), it is unlikely that these could be maintained for protracted periods of time (Bla96).

* See section 2.3.1 for a description of basal metabolic rate.

In addition to directed movement, involuntary movements also use up energy. During periods when energy consumption is too high, individual differences in fat storage could partly be the result of involuntary movements (Lev99).

The influence of the PAL value on the degree of physical activity has been summarized in table 2.3.

Table 2.3 PAL values based on $^2\text{H}_2$ ^{18}O research (Bla96).

lifestyle	PAL value
people who spend the entire day sitting or lying down	1.2
seated work without breaks, with little or no exercise in free time	1.4-1.5
seated work interspersed with periods spent walking round, with little or no exercise in free time	1.6-1.7
standing work	1.8-1.9
considerable effort used both at work and during free time	2.0-2.4
highest reported PAL value (extreme physical exertion)	+ 5.0

Many Dutch adults exercise far too little. This is characterized by PAL values of between 1.5 and 1.6. An increase in 24-hour energy consumption (Pat95) and more physical activity (Ber90, Man99) would reduce the risk of coronary heart disease. The Committee emphasizes that even a slight increase in physical activity can produce measurable health gains. American experts advocate at least 30 minutes of moderately energetic exercise on a daily basis (Pat95). By this means, the PAL value can be increased by 0.03 to 0.09.* One example of moderately energetic exercise is walking at a speed of four kilometres per hour (Ain93). In a recent study of American women, it was found that taking brisk walks for a total of at least 3 hours a week offered protection against coronary heart disease (Man99). There are indications that physical exercise can also play a part in the prevention of overweight, especially in people with a fat-rich diet (Lis97). It is also claimed that physical activity helps prevent cancer of the colon and possibly also breast cancer (Col97, Fri98, Mar97, Ver00).

For a summary of energy consumption during specific activities, the Committee recommends the publications by Ainsworth et al (Ain93, Ain00). The Committee

* At a low level of physical activity the PAL value will be 1.5. Activities involving a moderate level of effort are defined as activities in which the ratio between energy consumption and basic metabolic rate is from 3 to 6. Thus, relative to a low level of activity, this represents an increase in the PAL value by 1.5 to 4.5. Thirty minutes is 0.02 times the length of a day. If individuals with a low level of physical activity undertake 30 minutes of moderately intense activity, then their PAL value will increase by 0.02 times 1.5 to 4.5 (= 0.03 to 0.09).

stresses that an increase in physical activity must be substantial in order to produce a measurable change in the PAL value (see also the footnote at the next page).

Genetic factors

Little is known about the influence of genetic factors on body weight (Bou90, Hei95a, Ran98). There is some evidence, partly obtained from research performed on twins, that genetic factors determine 40-70% of energy efficiency (Bou90).

2.3 Estimated average requirement

The Committee has derived no adequate intake or recommended dietary allowance for energy. Both dietary reference intakes are above the personal requirement for (virtually) all individuals (see section 1.2). This would have adverse effects in the case of energy, since overconsumption leads to an increase in body weight.

The Committee has only derived the estimated average requirement for energy. This value is of little relevance to the individual since, in order to keep body weight constant, energy intake must correspond to individual requirement. However, on the basis of the data in this chapter, it is possible to estimate an individual's energy requirement. Using table 2.3 it is possible to estimate which PAL value applies to a given individual (see section 2.2.2). Then, using the predictive formula from table 2.4, it is possible to estimate that individual's basal metabolic rate on the basis of their body weight (see section 2.3.1). The individual energy requirement can then be calculated, since it is the product of basal metabolic rate and the PAL value.

2.3.1 Derivation methods

The Committee calculates the estimated average requirement for energy in infants of up to one year of age by adding 24-hour energy consumption (estimated using the $^2\text{H}_2^{18}\text{O}$ method) to the accretion costs of growth. For the other age groups, the Committee estimates the average energy requirement as the product of the average PAL value (estimated using the $^2\text{H}_2^{18}\text{O}$ method) and the basal metabolic rate. For groups up to 18 years of age this is supplemented by the accretion costs of growth.

In the 1989 report entitled Dietary Reference Intakes in the Netherlands, 24-hour energy consumption was determined by estimating each of the factors that contribute to energy consumption* and then adding them together (VR92). This is known as the factorial method. One drawback of this method is that one of the factors, the energetic

* The individual factors that determine energy consumption are the basal metabolic rate, diet-induced thermogenesis and energy consumption resulting from physical activities.

cost of physical activity, cannot be measured reliably. Since the Committee now has research results (obtained using the $^2\text{H}_2^{18}\text{O}$ method) for the majority of groups, the factorial method has become virtually superfluous. In this recommendation, the latter method has only been used for the purpose of estimating the average energy requirement during pregnancy and lactation.

The measurement methods that have been outlined are explained below.

The doubly-labelled water method - or $^2\text{H}_2^{18}\text{O}$ method

In the present recommendation, the estimated average requirement has principally been based on research results obtained using the relatively new doubly labelled water method or $^2\text{H}_2^{18}\text{O}$ method. The Committee attaches a great deal of importance to this method since it is the only non-invasive method for accurately measuring 24-hour energy consumption in the normal day-to-day situation (i.e. without affecting an individual's usual pattern of activity). In children, the measured value reflects the average energy consumption throughout the previous 5-10 days. The equivalent period in adults is 10-20 days.

On the basis of a validation study in which the $^2\text{H}_2^{18}\text{O}$ method was compared to the respiration chamber method, accuracy is estimated at 10% and reproducibility at 6-10% (IDEC90, Spe98). The $^2\text{H}_2^{18}\text{O}$ method also appears to provide a valid estimate of 24-hour energy consumption during the first 12 months of life (But96). In deriving the estimated average requirement, the Committee has avoided the use of data obtained from respiration chamber studies since these measurements cannot reflect the normal day-to-day situation.

Data obtained using the $^2\text{H}_2^{18}\text{O}$ method is used to estimate 24-hour energy consumption (excluding the energy costs of growth) in infants of up to 1 year of age. This method is used to determine the average PAL value for all other age groups. This value is a measure of the average level of physical activity (see section 2.2.2). The Committee assumes that, on average, infants, young children and adolescents have an adequate level of physical activity (see section 2.3.2). However, in the case of adults, the Committee estimates that the average level of physical activity is too low. Accordingly, the same applies for the average PAL value. In section 2.2.2, the Committee covers the influence of physical activity on PAL values in adults.

Basal metabolic rate

The basal metabolic rate reflects the energy consumption of individuals at rest and in the post-absorptive state that occurs in a thermoneutral room. Energy consumption during sleep is about 5% lower (Bla96).

Table 2.4 Calculation of the basic metabolic rate in MJ/d from body weight in kg (WCMV94).

category		basal metabolic rate = a + b x body weight	
		a	b
boys/men	0 to 2 years of age	- 0.13	0.2490
	3 to 9 years of age	+ 2.11	0.0950
	10 to 17 years of age	+ 2.75	0.0740
	18 to 29 years of age	+ 2.84	0.0640
	30 to 59 years of age ^a	+ 3.67	0.0485
	60 to 74 years of age	+ 2.93	0.0499
	75 years of age and above	+ 3.43	0.0350
girls/women	0 to 2 years of age	- 0.13	0.2440
	3 to 9 years of age	+ 2.03	0.0850
	10 to 17 years of age	+ 2.90	0.0560
	18 to 29 years of age	+ 2.08	0.0615
	30 to 59 years of age	+ 3.47	0.0364
	60 to 74 years of age	+ 2.88	0.0386
	75 years of age and above	+ 2.61	0.0410

^a Sample calculation: The basal metabolic rate of a man aged 50 and weighing 85 kilograms is estimated at $3.67 + 0.0485 \times 85 = 7.8$ MJ/d.

If no measurements of the basal metabolic rate are available, it can be estimated on the basis of body weight, age and sex*. Various research groups have drawn up predictive formulae (Eli92). In 1985, the FAO/WHO/UNU opted for the Schofield formulae, which are based on approximately 7,000 measurements (FAO85, Sch85). Since then, these have been widely used for drawing up energy recommendations. Schofield's data included very little data on the elderly. As a result, the European Commission's Scientific Committee for Food has drawn up new formulae for the older age groups (WCMV94). The Committee uses these partly modified Schofield formulae

* Formulae that predict basal metabolic rate on the basis of height, weight, age and gender have virtually the same predictive value as formulae based on weight, age and gender. For this reason, they have not been incorporated in this recommendation.

(table 2.4) and the reference weights (see section 1.6) to calculate the basic metabolic rate of individual age and gender groups.* Differences in fat-free body mass (body weight minus body fat mass) determine a large part of the variation in basal metabolic rate between individuals. However, after correction for age, fat-free mass, body fat mass and measurement errors, the intra-individual coefficient of variation still amounts to 10% (Wes89). Thus the formulae in table 2.4 only provide a rough estimation of an individual's basal metabolic rate.

The energy costs of growth

The energy costs of growth consist of accretion costs and synthesis costs. Tissues have a variety of constituents, including proteins and fats. The amount of energy stored in newly formed tissues (tissue protein contains 24 kJ per gram and tissue fat contains 39 kJ per gram) is designated by the term 'accretion costs'. The Committee estimates the accretion of body protein and body fat as the difference between the amounts of body protein and body fat at the beginning and end of each age-group period. These amounts are calculated on the basis of body weight (TNO98) and the body's protein and fat percentages (Fom82) at these age-group boundaries. The energy costs of growth have a second component, the costs of synthesis. The energy cost of laying down one gram of tissue protein is 33 kJ. The equivalent value for tissue fat is 7 kJ. Thus the total energy costs of growth are 57 kJ per gram of protein and 46 kJ per gram of fat (Rob88).

The 24-hour energy consumption of growing individuals (as measured using the $^2\text{H}_2^{18}\text{O}$ method) includes the synthesis costs but excludes the accretion costs. In such cases, the estimated average requirement is calculated as the 24-hour energy consumption plus the accretion costs.

When estimating 24-hour energy consumption using the factorial method, both the accretion costs and the synthesis costs must be taken into account. Here, the factorial method involves calculating the sum of the basal metabolic rate, food-induced thermogenesis, energy consumption due to physical activity and the energy costs of growth.

* Since there is some evidence that the formulae overestimate the basal metabolic rate, a re-evaluation should be carried out (She96).

2.3.2 Age groups from birth to 11 months

24-hour energy consumption using the $^2\text{H}_2^{18}\text{O}$ method

$^2\text{H}_2^{18}\text{O}$ measurements in British and American infants showed that 24-hour energy consumption per kilogram of body weight increases during the first few months of life (But96). This agrees with the findings for Dutch infants. On the basis of that Dutch study (Bru98) and a recent American publication (But00), the Committee estimates that the average 24-hour energy consumption for the 0 to 2-month and 3 to 5-month age groups at 0.30 MJ/kg. The equivalent value for the 6 to 11-month age group was 0.33 MJ/kg.

Growth (accretion costs)

During the first three months of life, a baby's body-fat percentage increases from approximately 15% to approximately 24%, and the body-protein percentage falls by approximately 1%. Between the ages of 3 to 5 months and from 6 to 11 months, the body-fat percentage increases to approximately 26%, while the body-protein percentage remains about the same (Fom82). The Committee feels that the minor differences in weight increase and body composition between girls and boys in these age groups are not sufficient reason to draw distinctions on the basis of gender. When data on body-fat and body-protein percentages are combined with the Dutch data on weight for the beginning and end of every age group (see section 2.3.1), this generates the following estimates for the average daily accretion costs: for babies aged from 0 to 2 months 0.5 MJ/d or 0.10 MJ/kg, for the 3 to 5-month age group 0.3 MJ/d or 0.05 MJ/kg and for the 6 to 11-month age group 0.1 MJ/d or 0.01 MJ/kg.

Estimated Average Requirement

The estimated average requirement consists of 24-hour energy consumption plus accretion costs (table 2.5). Throughout the first year of life it appears that there is a gradual increase in the energy requirement. However, the value per kilogram of body weight shows a gradual reduction over the same period.

Table 2.5 Derivation of babies' estimated average requirement.^a

category	factor	MJ/kg per day	MJ/d
0 to 2 months	24-hour energy consumption	0.30	1.4
	accretion costs	0.10	0.5
	estimated average requirement	0.39	1.8
3 to 5 months	24-hour energy consumption	0.30	2.1
	accretion costs	0.05	0.3
	estimated average requirement	0.35	2.4
6 to 11 months	24-hour energy consumption	0.33	2.9
	accretion costs	0.01	0.1
	estimated average requirement	0.35	3.0

^a The differences between the sum of 24-hour energy consumption plus accretion costs and the estimated average requirement result from rounding off the values.

2.3.3 Age groups from 1 to 18 years of age

24-hour energy consumption using the $^2\text{H}_2^{18}\text{O}$ method

On the basis of the results of studies in which the doubly-labelled water method was used, average PAL values have been estimated for boys and girls aged from 1 to 5, from 6 to 13 and from 14 to 19 years of age (Tor96). The basal metabolic rate of each group was calculated using the formulae in table 2.4. Next, the 24-hour energy consumption (excluding the energy costs of growth) was calculated by multiplying the PAL value by the basal metabolic rate.

Growth (accretion costs)

Fat and protein accretion during growth is calculated by multiplying the body-fat and body-protein percentages by the average body weight at the boundaries of each age-group period (see section 2.3.1). Data on body-fat percentages and body-protein percentages obtained from the literature were used for the 1, 4 and 9 year boundaries (Fom82). The Committee used assumed values for the 14-year and 19-year boundaries. The assumption was that boys aged 14 and 19 have 17% body protein, whereas the equivalent value for girls is 15%. The assumed values for body fat in boys aged 14 and 19 were 14% and 15% respectively, and 19% and 20% for girls. Energy accretion in MJ/d was calculated on the basis of the above assumptions. For the age groups between 1 and 18 years of age this appeared to vary between 0.05 and 0.13 MJ/d.

Estimated average requirement

The estimated average requirement is calculated as the product of the PAL value and the basal metabolic rate, plus the energy costs of growth (see table 2.6). It appears that, in these age groups, growth (accretion) only makes a small contribution to the energy requirement.

There is little data concerning 24-hour energy consumption in Dutch children. Average PAL values of 2.0 and 1.7 have been reported for healthy seven to ten-year-old boys and girls respectively (Ber95). These values correspond to the data contained in table 2.6. The PAL values show that, on average, the activity pattern in these age groups is still at an adequate level, even though the adequate PAL value for girls from 14 to 18 years of age is 1.8 rather than 1.7.

Table 2.6 Derivation of the average daily energy requirement.

category	reference weight	basal metabolic rate (BMR) ^a	PAL value ^b	BMR x PAL	average accretion costs	estimated average requirement ^c
	kg	MJ/d		MJ/d	MJ/d	MJ/d
<i>boys</i>						
1 to 3 years of age	14	3.4	1.5	4.99	0.05	5.0
4 to 8 years of age	24	4.4	1.6	7.09	0.06	7.2
9 to 13 years of age	40	5.8	1.8	10.44	0.12	10.6
14 to 18 years of age	65	7.5	1.8	13.87	0.11	14.0
<i>girls</i>						
1 to 3 years of age	13.5	3.2	1.5	4.66	0.05	4.7
4 to 8 years of age	23.5	4.0	1.6	6.42	0.09	6.5
9 to 13 years of age	41	5.3	1.8	9.42	0.13	9.5
14 to 18 years of age	59	6.1	1.7	10.31	0.07	10.4

^a The basal metabolic rate is estimated on the basis of reference weight, age and gender (see table 2.2).

^b The PAL value is based on data derived using the $^2\text{H}_2^{18}\text{O}$ method (Tor96).

^c Calculated as BMR x PAL value plus the average accretion costs.

2.3.4 Age groups above 18 years of age

The PAL value for inactive individuals is between 1.4 and 1.7 (see section 2.2.2).

When deriving the estimated average requirement, the Committee works on the basis of an average PAL value of 1.7 for adults. This value decreases with increasing age. In a group of elderly men aged from 70 to 80, from the Dutch town of Zutphen, the average

PAL value was 1.5 (Saris WHM, personal communication). The Committee assumes an average PAL value of 1.6 for individuals aged 51 to 70.

For reasons of public health, it is important to increase the level of physical activity (see section 2.2.2). The Committee defines the PAL value for an adequate level of activity as 1.9 for the age groups between 19 and 50, 1.8 for the 51 to 70 age group, and 1.7 for individuals above the age of 70. The value of 1.8 for healthy and active elderly people is supported by the results of a Dutch study (Sch97).

A meta-analysis of studies carried out in the Netherlands and abroad shows that 70% of men and 90% of women have a PAL value of less than 1.9 (Bla96). The Committee assumes that many adult Dutch people do not lead sufficiently active lives.

The Committee calculates the estimated average requirement for adults by multiplying basal metabolic rate and PAL value by the low average level of physical activity in the Netherlands (table 2.7).

Table 2.7 Derivation of the estimated average requirement for energy for adults.

category	reference weight	basal metabolic rate	PAL values		estimated average requirement
			at an adequate level of physical activity	at the low average level of physical activity in the Netherlands	
<i>men</i>	<i>kg</i>	<i>MJ/d</i>			<i>MJ/d</i>
19 to 30 years of age	75	7.6	1.9	1.7	12.9
31 to 50 years of age	72	7.2	1.9	1.7	12.2
51 to 70 years of age	74	6.9	1.8	1.6	11.0
> 70 years of age	74	6.2	1.7	1.5	9.3
<i>women</i>					
19 to 30 years of age	64	6.0	1.9	1.7	10.2
31 to 50 years of age	62	5.7	1.9	1.7	9.7
51 to 70 years of age	64	5.6	1.8	1.6	9.0
> 70 years of age	63	5.2	1.7	1.5	7.8

2.3.5 Pregnancy

During pregnancy, energy is stored in newly developed tissue, in the form of fats and proteins. The average increase in the body fat mass of Dutch women during pregnancy has been estimated to be 2.4 kg (Raa87, Spa93). The equivalent value for women from other Western countries is 3.3 kg (Pre96). The difference may be due to the method of

measurement used, on the other hand it may indeed represent a lower increase in fat levels in the Netherlands. The Committee bases its calculations on an average increase in fat levels during pregnancy of 3.0 kg (Pre96).

The basal metabolic rate increases gradually during pregnancy. At the end of pregnancy, the basal metabolic rate is approximately 20% higher than it was before the pregnancy. Throughout the entire course of the pregnancy, the average increase is 0.6 MJ/day (Pre96).

Energy consumption while walking at a set speed remains virtually unchanged during the first half of pregnancy. After this it increases rapidly until it reaches approximately +20% at the end of the pregnancy. There is a small increase in energy consumption while cycling at a fixed resistance (+11% at the end of the pregnancy), probably because the energy costs of cycling are less affected by body weight than are those associated with walking. Approximately 5% of the increase can be attributed to the increase in basal metabolic rate (Pre96). Day to day life consists of a combination of activities, some of which are markedly affected by body weight (such as walking) whereas others (for example, seated activities) are only marginally affected. The Committee estimates the average increase in net energy consumption associated with physical activities*, (based on an unchanged pattern of activity) during the three trimesters of pregnancy at 0%, 4% and 8% respectively.

On the basis of available research results, the Committee assumes that food-induced thermogenesis accounts for 10-15% of the total energy intake in both non-pregnant and pregnant women (Pre96). If energy intake increases during pregnancy then food-induced thermogenesis increases in absolute terms.

Using the factorial method and assuming an unchanged pattern of activity, the increase in energy requirement during pregnancy can be estimated at an average of 1.5 MJ/d (upper section of table 2.8).

It appears that Dutch women become gradually less active during the course of pregnancy (Raa87, Spa93). This adaptation has been estimated to produce an average saving of 0.5 to 0.6 MJ per day (Raa87). The second section of table 2.8 shows estimates based on studies using the $^2\text{H}_2^{18}\text{O}$ -method (Gol93, Kop99, Pit99). The results of this type of research show that there are major differences in the energy costs of pregnancy and in the way in which pregnant women satisfy their energy requirement. During the first two trimesters of pregnancy, the average values obtained in this way are 0.6 MJ/d lower than the estimates based on the factorial method. In the third trimester, however, they are 0.4 MJ/d higher. On the basis of the $^2\text{H}_2^{18}\text{O}$ method, the average increase in energy requirement during pregnancy has been estimated to be 1.2 MJ/d.

* Net energy consumption during physical activity is energy consumption minus basal metabolic rate.

Table 2.8 Increase in energy requirement during pregnancy, in MJ/d.

	trimester of the pregnancy			entire pregnancy
	1	2	3	
<i>factorial method, based on an unchanged pattern of activity</i>				
energy accretion	0.4	0.7	0.5	0.5
synthesis costs of growth	0.1	0.1	0.1	0.1
basal metabolic rate	0.2	0.4	1.1	0.6
net costs of physical activity ^a	0	0.1	0.2	0.1
food-induced thermogenesis ^b	0.1	0.2	0.3	0.2
average increase in energy requirement	0.8	1.5	2.2	1.5
<i>²H₂¹⁸O method</i>				
24-hour energy consumption (results obtained using the ² H ₂ ¹⁸ O method) ^c	- 0.2	0.2	2.1	0.7
energy accretion (see above)	0.4	0.7	0.5	0.5
average increase in energy requirement	0.2	0.9	2.6	1.2

^a Estimated value prior to pregnancy 2.5 MJ/d. Increase during the three trimesters of pregnancy 0%, 4% and 8% respectively.

^b 12.5% of the increase in energy intake = 12.5% of the total energy costs of pregnancy

^c Weighted average of 69 women (For92, Gol93 and Kop99).

The Committee concluded that the average energy cost of pregnancy is 1.5 MJ/day. The average extra energy requirement is lower, however. This is because in general, during pregnancy, women in Western countries are less physically active. Based on the results of research using the ²H₂¹⁸O method, the Committee estimates the extra energy requirement during pregnancy to be 1.2 MJ/d.

2.3.6 Lactation

The additional requirement for energy during lactation is equal to the energy value of human milk plus the energy required to produce it. Each millilitre of human milk contains approximately 2.6 kJ of energy that can be metabolized (Bru98). The total energy content of human milk is approximately 5% higher, or 2.7 kJ/ml (Pre96). During lactation, the average amount of energy secreted via human milk (800 ml/d) each day is approximately 2.2 MJ.

The Committee has calculated the energy required for the production of human milk by assuming a value for the efficiency with which food energy is converted to human

milk energy. This conversion efficiency is at least 80% (Pre96). Based on the values mentioned above, the energy cost of lactation is 2.7 MJ per day. On average, the amount of body fat falls by approximately 0.5 kg per month during lactation. As a result, the additional energy requirement is approximately 19 MJ per month lower than the energy cost associated with lactation (Pre96). The Committee estimates the average extra energy requirement during lactation to be 2.1 MJ per day.

Like pregnancy, lactation may also lead to a reduced level of physical activity (Spa94). This can reduce the energy requirement. Future research involving the $^2\text{H}_2^{18}\text{O}$ method should, it is hoped, provide a definite answer concerning the size of this saving in terms of energy requirement.

2.4 Comparison with other reports on dietary reference intakes

Annex B, table B2 shows the estimated average requirement for people of various ages, as derived in the present recommendation and from values in reports prepared in other countries. The dietary reference intakes that have been derived in the present recommendation differ little from those that appeared in the 1989 report on Dutch dietary reference intakes. They are generally in the area of the highest values quoted in the foreign reports, but the value for 15-year-old boys is higher than those in the other reports. The differences partly result from the use of different reference weights (see table B1). In addition, the present recommendation uses a higher PAL value for 15-year-old boys (1.8) than in most of the other reports (Scandinavian countries, Great Britain and the European Community: 1.6; previous Dutch dietary reference intakes: 1.6-1.7; United States: 1.7; German-speaking countries: 1.75).

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Proteins

Summary 65

3.1 Introduction 65

3.1.1 Nomenclature, properties and occurrence 65

3.1.2 Physiological significance 65

3.1.3 Deficiency symptoms 66

3.1.4 Chronic diseases 66

3.2 Factors that influence requirement 69

3.2.1 Dietary factors 69

3.2.2 Other factors 70

3.3 Estimated average requirement and recommended dietary allowance 70

3.3.1 Derivation method 70

3.3.2 Values 72

3.4 Tolerable upper intake level 75

3.5 Comparisons with other reports on dietary reference intakes 75

References 76

Summary

The average protein requirement was derived from the amount of nitrogen lost via then urine, faeces, nails and sweat, plus any additional nitrogen that may be required for growth, pregnancy and lactation. This quantity of nitrogen was converted to a corresponding amount of protein by multiplying it by 6.25. When calculating the protein requirement, the Committee has also taken into account the efficiency (70%) with which body protein is synthesized from amino acids. The Committee assumes that the nutritional protein content of the average in the diet in the Netherlands is of optimum quality. The protein requirements of individuals with a lacto-ovo vegetarian dietary pattern and a vegan dietary pattern are respectively 1.2 and 1.3 times higher than the requirement of individuals with a mixed diet. For information on the average requirements and recommended dietary allowances of individuals on a mixed diet, see tables 3.1 and 3.2 in section 3.3.2. For details of the tolerable upper intake level, see section 3.4.

3.1 Introduction

3.1.1 *Nomenclature, properties and occurrence*

Proteins are chains of amino acids. The specific properties of a protein depend on the type of amino acids it contains and on the sequence in which they are linked together. Major sources of protein in the Netherlands are meat, milk, eggs and cereals.

3.1.2 *Physiological significance*

Protein is one of the building blocks used in every living organism. It is important for virtually all of the processes of life. Proteins perform specific functions within the body, such as the transport of various substances, enzyme action, hormonal and receptor functions, and antibody action.

In the gastrointestinal tract, proteins derived from food are split into their component amino acids. Once they have been absorbed into the blood, these amino acids are used to synthesize the characteristic proteins of the body. In addition to their role as the building blocks of proteins, amino acids are involved in numerous regulatory processes. For example, they can act as neurotransmitters, hormones or as precursors for either of these types of molecule. In addition, amino acids supply energy.

Amino acids are classified as either essential or nonessential. The body can synthesize nonessential amino acids from other amino acids, in a process known as

transamination. Essential amino acids are those that cannot be synthesized in the body. For this reason, it is important that proteins in the diet contain sufficient essential amino acids. The essential amino acids are phenylalanine, histidine, isoleucine, leucine, lysine, methionine, threonine, tryptophan and valine. The nonessential amino acids are alanine, arginine, asparagine, aspartic acid, cysteine, cystine, glutamine, glutamic acid, glycine, hydroxyproline, proline, serine and tyrosine. In certain clinical pictures, the synthesis of six of the nonessential amino acids in the body may be insufficient, requiring supplements to be added to the diet. These so-called semi-essential amino acids are arginine, asparagine, glutamine, glycine, proline and serine.

Body proteins are continually being broken down and synthesized. Depending on the protein involved, replacement rates range from a few hours to several months. A given quantity of amino acids are lost during each replacement cycle. The nitrogen that was contained in these amino acids leaves the body via the urine, in the form of urea. Small quantities of nitrogen are also lost via the faeces and the skin (shed flakes of skin, sweat and hairs).

3.1.3 *Deficiency symptoms*

Long-term protein deficiency has far-reaching consequences. These first become apparent in those functions that involve proteins and cells with a high replacement rate, such as the cells of the intestinal epithelium and those of the immune system. Growing children will also be affected by growth disorders. The clinical picture that develops as a result of protein malnutrition is referred to as 'kwashiorkor'. When combined with excessively low energy intake, this gives rise to 'marasmus'. Diets with an extremely low protein content ultimately result in death.

3.1.4 *Chronic diseases*

Overweight

In iso-energetic exchange, proteins produce a more pronounced feeling of satiation than do either fats or carbohydrates (Dou97). Compared to carbohydrates and fats, proteins are a poor source of energy for the body, since energy consumption following protein ingestion increases relatively rapidly (see section 2.2.1). In theory, the result of these two effects is that a diet that is rich in protein will tend to reduce the risk of excessive energy intake. During an intervention study in which overweight individuals were given a limited-energy diet, it was found that a protein-rich diet (25 percent of the energy in the form of protein) led to a greater reduction of body weight than did a diet with a normal protein content (12 percent of the energy in the form of protein) (Sko99).

However, individuals with high protein intake levels on one day will usually opt for a diet with a relatively low protein content on the following day (Wes96). Accordingly, over long periods of time, there is very little variation in protein intake (Dou97, Hil95, Rol99).

The Committee feels that the lack of data makes it impossible to formulate any conclusions about the effect of proteins on body weight. Limited-energy diets with high protein contents may be more successful than those with low protein contents. In this field, no research has been carried out into individuals with an ideal body weight.

Coronary heart disease

Prospective cohort studies into the effect of protein consumption on the development of coronary heart disease have produced somewhat ambiguous results. One cohort study seemed to suggest that a high protein intake level increased the risk of coronary heart disease (McG84), while another cohort study indicate that this has a protective effect (Hu99)*. However, most studies of this type show no connection between protein consumption and the occurrence of coronary heart disease (Feh93, Gor81, Kro84, Kus85).

The protein content of a limited-energy diet has no effect on the concentration of lipids in the blood (Sko99). The type of protein involved may also be important in this connection. The results of a meta-analysis of intervention studies indicate that soya protein reduces the total cholesterol concentration in the blood, as well as the concentrations of LDL cholesterol and triglycerides (And95). However, the extent to which this effect is attributable to the protein itself is not clear. The authors feel that the observed effect is largely due to the phyto-oestrogens which occur in soya protein.

The results of a cross-sectional study indicate that protein in the diet reduces blood pressure. However, this finding is not supported by data from an intervention study (Oba96).

The Committee concludes that protein probably has no effect on the development of coronary heart disease.

Cancer

The Committee has used using a literature review produced by the World Cancer Research Fund (WCRF97) to evaluate the influence of protein on the development of cancer. With regard to cancer of the colon, the results of controlled studies of patients

* In a study carried out by Hu *et al.*, protein intake in the lowest quintile was 15 percent of total energy intake, while in the highest quintile it was 24 percent of total energy intake (Hu99).

generally indicate that there is an increased risk, while other studies show that there is a protective effect. The five prospective cohort studies that are available have not demonstrated a link with cancer of the colon. In the case of breast cancer, three of the four controlled studies of patients show that animal protein has a detrimental effect.

The Committee feels that the consumption of protein is unlikely to influence the risk of cancer*.

Osteoporosis

Protein in the diet increases the loss of calcium via the urine (Ker98, Wea99, Zem88). This can adversely affect the skeleton. However, a high protein diet is also rich in phosphate, which reduces calcium excretion (Zem88). The results of a prospective cohort study in young women indicate that a high protein intake reduces bone synthesis (Rec92). In another cohort study, women aged 55-69 on a high protein diet sustained fewer fractures than those on a diet with a lower protein content (Min99). In a third cohort study in the elderly, no connection was found between protein consumption and the risk of fractures (Fes96).

The Committee feels that the lack of data makes it impossible to formulate any conclusions about the effect of proteins on the development of osteoporosis.

Kidney disorders

High levels of protein consumption may be harmful to the kidneys (Jac99). This suspicion is partly based on the fact that individuals suffering from kidney disease benefit from a reduction in the protein content of the diet (Ped96). In the case of healthy, overweight test subjects, a protein-rich, limited energy diet did not appear to affect kidney function (Sko99). People with non-insulin-dependent diabetes mellitus are at higher risk of developing kidney disease than are healthy individuals. In this group also it was found that a reduction of protein consumption over a period of two to three years has no effect on kidney function (Pij99).

The Committee concludes that the consumption of protein probably has no effect on the development of kidney diseases.

* This recommendation is concerned with nutrients, rather than with foodstuffs. The Committee also points out that a high consumption of red meat may increase the risk of breast cancer and colon cancer (Bin99, DH98, Hil99, WCRF97).

3.2 Factors that influence requirement

3.2.1 *Dietary factors*

Protein quality

The quality of a protein is dependent on its digestibility and on the levels of essential amino acids it contains relative to the requirement for these amino acids. The so-called limiting amino acid is the essential amino acid with the lowest concentration relative to the requirement.

The Committee uses the Protein Digestibility-Corrected Amino Acid Score (or PDCAAS) as a measure of protein quality (FAO90, Sch00). The PDCAAS is the level of the limiting essential amino acid in the protein, expressed as mg per gram of protein, divided by the requirement for this amino acid in children of up to 4 years of age (also expressed in mg per gram of protein) (FAO85), multiplied by the digestibility of the protein. The PDCAAS of a mixture of proteins describes the extent to which these proteins supplement one another's limiting amino acid.

The 1997-1998 Dutch Food Consumption Survey showed that, on average, the Dutch consume about twice as much animal protein as vegetable protein (Hul98). In determining protein quality, the Committee worked on the basis of proteins from meat, milk and wheat in the ratio 1:1:1. The PDCAAS of this mixture is 100%. This means that in this protein mixture none of the essential amino acids is limiting, so optimum use can be made of all essential amino acids in the synthesis of body proteins.

In the diets of lacto-ovo vegetarians and vegans, lysine is the limiting amino acid. Assuming that milk proteins and wheat proteins are present in a 1:1 ratio, then the PDCAAS for a lacto-ovo vegetarian diet is estimated at 84%. In calculating the PDCAAS for a vegan diet, the Committee assumed a ratio of wheat proteins to soya proteins of 1:1. It is estimated that this diet has a PDCAAS of 77%.

Other nutrients

If energy intake is insufficient, the body uses more proteins as a source of energy. This causes an increase in the requirement for protein in the diet. When there is an excessive energy intake, this has the opposite effect (Cal75, Gar76). In addition, a certain level of carbohydrate intake is required to counter protein breakdown (see sections 5.1.2 and 5.3.1). The body requires vitamin B₆ for the synthesis of non-essential amino acids. Vitamine B₆ deficiency can cause non-essential amino acids to become essential.

When establishing the dietary reference intakes for protein, the Committee assumes that the intake of energy, carbohydrates and vitamin B₆ is adequate.

3.2.2 *Other factors*

In physically active people, protein intake influences the development of muscle mass (Wol00). For information on this topic, see the report produced by a working group of the European Commission's Scientific Committee for Food, concerning the nutritional requirements of athletes (SCF00). According to this report, athletes who perform at peak level for protracted periods of time have a slightly elevated protein requirement of 1.2 to 1.4 grams per kilogram per day. People who do weight training also have an elevated protein requirement, of 1.3 to 1.5 grams per kilogram per day. After several years of training, this group's protein requirement would fall slightly*.

3.3 **Estimated average requirement and recommended dietary allowance**

3.3.1 *Derivation method*

The protein requirement is determined by the amounts of essential and non-essential amino acids that are required to build up the proteins in the body. In theoretical terms, it would be more appropriate to establish dietary reference intakes for amino acids rather than for proteins. There are objections to this approach, however, as free amino acids do not occur in foodstuffs. They are invariably present in the form of proteins.

The protein contained in the diet must be sufficient to compensate for any loss via the urine, faeces, hair, nails and sweat. If appropriate, it must also be sufficient to meet the needs of growth, pregnancy or lactation.

The nitrogen loss associated with a protein-free diet is indicated by the term 'obligatory nitrogen loss'. Balance studies show that the protein requirement is higher than the intake that just compensates for the obligatory nitrogen loss, even if the individual in question is not growing, pregnant or lactating. The nitrogen balance is only in equilibrium if the intake is 1.43 times higher. It appears that the synthesis of body-specific proteins from amino acids has an efficiency of $(1/1.43) \times 100 = 70\%$ (FAO85).

The degree to which the body can use amino acids derived from food for the synthesis of body proteins is dependent on the quality of the protein. The Committee describes protein quality in terms of the PDCAAS (see section 3.2.1).

* The use of amino acids instead of proteins may have adverse effects. This is particularly true for pregnancy and lactation, and for children up to 13 years of age (GR99).

The protein requirement, in grams per day, is estimated as follows:

$$\text{protein requirement} = [(\text{nitrogen loss} + \text{nitrogen requirement for growth}) \times 6.25] / (0.70 \times \text{PDCAAS})$$

nitrogen loss = obligatory nitrogen loss via urine, faeces, hair, nails and sweat, in g/d.

nitrogen requirement for growth = nitrogen requirement for growth, pregnancy or lactation, in g/d.

6.25 = factor for converting an amount of nitrogen to the equivalent amount of protein (both in grams).

0.70 = factor for the efficiency with which body protein is synthesized from amino acids.

PDCAAS (Protein Digestibility-Corrected Amino Acid Score) = factor for protein quality.

The PDCAAS for the average Dutch diet is 1.00. The values for lacto-ovo vegetarian and vegan dietary patterns are 0.84 and 0.77 respectively (see section 3.2.1).

There are methods for measuring obligatory nitrogen loss. The 'factorial method' involves measuring the amounts of nitrogen lost via the urine, faeces, skin, hair and sweat after one week on a protein-free diet. The total of these losses is the obligatory nitrogen loss. The 'balance method' involves placing a test subject on a diet that causes a negative nitrogen balance. Next, the protein intake is increased step by step until it reaches a level at which there is no further improvement in the balance. On the basis of this data, it is possible to use linear regression to estimate the nitrogen loss that occurs in individuals on a protein-free diet. From the available data, the Committee concludes that the obligatory nitrogen losses for babies of up to one year of age amount to 63 milligrams per kilogram per day. The equivalent figure for all other age groups is 70 milligrams per kilogram per day (Dew96, FAO85).

The Committee has determined the nitrogen requirement for growth on the basis of the difference between the body's nitrogen contents at the boundaries that separate the age groups. To this end, the amount of protein (as a percentage of body weight) in the body at each of these boundaries is multiplied by the average weight at that age. Data on body-protein percentages obtained from the literature were used for the boundaries of all age-groups up to nine years of age (Fom82). The Committee assumes that the body protein content for boys aged 14 and 19 is 17%, and that the equivalent value for girls is 15%. The average weights at these age boundaries were derived from the growth diagrams obtained from a national study (Fre98, Fre00a, Fre00b, TNO98).

Section 3.3.2 gives the dietary reference intakes for individuals with an 'average Dutch diet'. The formula and the PDCAAS values show that the protein requirements of lacto-ovo vegetarians and vegans are higher than that of people on a mixed diet. Lacto-ovo vegetarians have a protein requirement that is $1/0.84 = 1.2$ times higher while the protein requirement for vegans is $1/0.77 = 1.3$ times higher.

3.3.2 Values

For all age groups, the average protein requirement (in grams per kilogram of body weight per day) is derived by means of the formula shown in section 3.3.1. Multiplying by the reference weight (see section 1.6) produces the estimated average requirement in grams per day. It is estimated that the coefficient of variation for differences between individuals in terms of their protein requirement (in grams per kilogram per day) amounts to 15% in the first year of life, and 12.5% for all other age groups (FAO85, Dew96). The Committee assumes that the coefficient of variation for the protein requirement (in grams per day) will be 15% for all age groups. The recommended dietary allowance is calculated as the estimated average requirement plus twice the standard deviation of the requirement (see section 1.2.2). Table 3.1 shows the dietary reference intakes. Explanations for some groups are provided below.

Infants

The Committee assumes that human milk is the best food for babies from birth up to an age of five months (see section 1.4.5). Baby's in this age group who receive no other food than mother's milk have an average protein intake is 1.2 grams per kilogram per day (Fom93). This is the adequate intake for babies fed human milk. The recommended dietary allowances indicated in table 3.1 are for formula-fed babies. These are for the birth to two-month age group (1.8 grams per kilogram per day) and for the three-month to five-month age group (1.4 grams per kilogram per day). This age group has been divided into two, due to the rapid growth that occurs in the first few months.

Adults

The protein requirement for the elderly corresponds to that of young adults (Cam96, Kur00, Mil96). When expressed as a percentage of the estimated average requirement for energy, the recommended dietary allowance increases from between eight and nine percent of energy intake in young adults to eleven percent in the oldest age group.

Pregnancy and lactation

During pregnancy, about 0.9 kilograms of protein is incorporated into the foetus, the placenta and breast tissue. On average, this amounts to an additional protein requirement of 5 grams per day, or an additional nitrogen requirement for growth of 8 milligrams per kilogram per day (table 3.2). Using experimental animals, it has been

Table 3.1 Estimated average requirement and recommended dietary allowances for boys and men.

	average nitrogen requirement		dietary reference intakes for protein		reference weight	dietary reference intakes for protein		
	losses ^a	growth ^b	estimated average requirement ^c	recommended dietary allowance		estimated average requirement ^d	recommended dietary allowance	recommended dietary allowance
	<i>mg/[kg.d]</i>	<i>mg/[kg.d]</i>	<i>g/[kg.d]</i>	<i>g/[kg.d]</i>	<i>kg</i>	<i>g/d</i>	<i>g/d</i>	energy % ^e
0 to 2 months ^f	63	89	1.4	1.8	5	7	9	8
3 to 5 months	63	57	1.1	1.4	7	8	10	7
6 to 11 months	63	36	0.9	1.2	9	8	10	6
1 to 3 years	70	14	0.8	0.9	14	11	14	5
4 to 8 years	70	9	0.7	0.9	24	17	22	5
9 to 13 years	70	8	0.7	0.9	40	28	36	6
14 to 18 years	70	4	0.7	0.8	65	43	56	7
19 to 30 years	70	0	0.6	0.8	75	47	61	8
31 to 50 years	70	0	0.6	0.8	72	45	59	8
51 to 70 years	70	0	0.6	0.8	74	46	60	9
> 70 years	70	0	0.6	0.8	74	46	60	11

^a Obligatory nitrogen losses (Dew96, FAO85).

^b Based on growth data for Dutch children (tables 1.3 and 1.4) and data on the protein content of the body, from Fomon (Fom82).

^a The estimated average requirement is g/kg per day is calculated using the formula in 3.3.1 (see also section 1.2.1). The coefficient of variation is 15% for the birth to eleven month age group, and 12.5% for all older age groups (Dew96, FAO85).

^a Calculated as the average protein requirement in g/kg per day times the reference weight (see also section 1.6). The Committee works on the basis of a coefficient of variation of 15%.

^c Calculated as the recommended dietary allowance of protein in g/d times 17 kJ per gram of protein, expressed as a percentage of the estimated average requirement for energy (see chapter 2).

^d The indicated dietary reference intakes are for baby's fed with infant formulae. For baby's who receive no other food than human milk, adequate intake equals the average intake (1.2 g/kg per day).

Table 3.2 Estimated average requirement and recommended dietary allowances for girls and women.

	average nitrogen requirement		dietary reference intakes for protein		reference weight	dietary reference intakes for protein		
	losses ^b	growth ^c	estimated average requirement ^c	recommended dietary allowance		estimated average requirement ^d	recommended dietary allowance	recommended dietary allowance
	<i>mg/[kg.d]</i>	<i>mg/[kg.d]</i>	<i>g/[kg.d]</i>	<i>g/[kg.d]</i>	<i>kg</i>	<i>g/d</i>	<i>g/d</i>	energy % ^e
0 to 2 months ^f	63	89	1.4	1.8	4.5	6	8	8
3 to 5 months	63	58	1.1	1.4	6.5	7	9	6
6 to 11 months	63	36	0.9	1.2	8.5	8	10	6
1 to 3 years	70	14	0.7	0.9	13.5	10	13	5
4 to 8 years	70	8	0.7	0.9	23.5	16	21	5
9 to 13 years	70	7	0.7	0.9	41	28	37	6
14 to 18 years	70	2	0.6	0.8	59	38	49	8
19 to 30 years	70	0	0.6	0.8	64	40	52	9
31 to 50 years	70	0	0.6	0.8	62	39	50	9
51 to 70 years	70	0	0.6	0.8	64	40	52	10
> 70 years	70	0	0.6	0.8	63	39	51	11
pregnancy	70	8	0.7	0.9	68	47	62	9
lactation	70	18	0.8	1.0	64	50	65	9

^b Obligatory nitrogen losses (Dew96, FAO85).

^c Based on growth data for Dutch children (tables 1.3 and 1.4) and data on the protein content of the body, from Fomon (Fom82).

^a The estimated average requirement in g/kg per day is calculated using the formula in 3.3.1 (see also section 1.2.1). The coefficient of variation is 15% for the birth to eleven month age group, and 12.5% for all older age groups (Dew96, FAO85).

^a Calculated as the average protein requirement in g/kg per day times the reference weight (see also section 1.6). The Committee works on the basis of a coefficient of variation of 15% (see also section 1.2.2).

^e Calculated as the recommended dietary allowance of protein in g/d times 17 kJ per gram of protein, expressed as a percentage of the estimated average requirement for energy (see chapter 2).

^f The indicated dietary reference intakes are for baby's fed with infant formulae. For baby's who receive no other food than human milk, adequate intake equals the average intake (1.2 g/kg per day).

shown that efficiency of protein metabolism increases during pregnancy (Nai80). The Committee is not convinced that this increase in efficiency occurs during human pregnancy. As a result, it uses the same value as for non-pregnant women.

During lactation, women secrete on average about 7 grams of protein per day via human milk (Fom93). This increases the nitrogen requirement by 18 milligrams per kilogram per day.

3.4 Tolerable upper intake level

Experimental animals fed on a high-protein diet have a lower life expectancy than those that are fed on lower levels of protein. Some recently published work describes mechanisms by which proteins could be harmful at high levels of intake (Dur99). An increase in protein consumption causes an increase in the body's acid burden. This may also cause the amount of calcium that is excreted via the urine to rise, thereby increasing the risk of osteoporosis. It has also been suggested that high levels of protein consumption might increase the risk of kidney damage and cancer. As yet there is no evidence to support any of these possible effects. However, it has been established that high protein intake is harmful for patients with poor kidney function. Nevertheless, this group is not addressed in the present recommendation, since these dietary reference intakes have been drawn up for the healthy population.

The results obtained by the studies described in section 3.1.4 show that levels of protein consumption of up to about 25 percent of total energy intake have no adverse effects on health (Ast00, Hu99, Sko99). However, there is little data available concerning higher levels of protein consumption (20-25 percent of total energy intake, and above). Exercising a certain degree of caution, the Committee has set the tolerable upper intake level for all age groups above one year of age at 25 percent of total energy intake. Babies should not have high levels of protein intake, since their kidneys are not yet fully developed. Thus, the tolerable upper intake level for the birth to five months age group has been fixed at 10 percent of total energy intake. For the next two age groups, the Committee has decided that there should be a gradual increase in the tolerable upper intake level. Accordingly, the level for babies aged from 6 to 11 months is 15 percent of total energy intake. This rises to 20 percent of total energy intake for the 1 to 3-year age group, and to 25 percent of total energy intake for children aged 4 and above.

3.5 Comparisons with other reports on dietary reference intakes

Annex B, table B3, compares the amounts of proteins that have been recommended in this report with the values for several age groups taken from other reports. The values

derived above are substantially lower than those given in the 1989 report on Dutch dietary reference intakes. The new dietary reference intakes conform more closely with the dietary reference intakes for the German-speaking countries, Great Britain, Europe and the United States. In the Scandinavian countries, recommended protein intake is substantially higher.

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Fats

Summary 81

- 4.1 Introduction 82
 - 4.1.1 Nomenclature and occurrence 82
 - 4.1.2 Terminology 83
 - 4.1.3 Physiological significance 84
 - 4.1.4 Influence on the development of chronic diseases 85
 - 4.1.5 Factors that influence requirement 87
-

- 4.2 Polyunsaturated fatty acids 88
 - 4.2.1 Deficiency symptoms 88
 - 4.2.2 Coronary heart disease 89
 - 4.2.3 Cancer 94
 - 4.2.4 Diabetes mellitus type 2 96
 - 4.2.5 Affects on the immune system 97
 - 4.2.6 Adequate intake 97
 - 4.2.7 Tolerable upper intake level 100
-

- 4.3 Monounsaturated fatty acids 101
 - 4.3.1 Coronary heart disease 101
 - 4.3.2 Cancer 102
 - 4.3.3 Diabetes mellitus type 2 102
-

4.3.4	Adequate intake	103
4.3.5	Tolerable upper intake level	103
<hr/>		
4.4	Total intake of monounsaturated fatty acids plus polyunsaturated fatty acids	103
4.4.1	Adequate intake range	103
<hr/>		
4.5	Saturated fatty acids	104
4.5.1	Coronary heart disease	104
4.5.2	Cancer	105
4.5.3	Diabetes mellitus type 2	106
4.5.4	Adequate intake	107
4.5.5	Tolerable upper intake level	107
<hr/>		
4.6	<i>Trans</i> fatty acids	108
4.6.1	Coronary heart disease	108
4.6.2	Diabetes mellitus type 2 and cancer	108
4.6.3	Adequate intake	109
4.6.4	Tolerable upper intake level	109
<hr/>		
4.7	Total fat	110
4.7.1	Overweight	110
4.7.2	Coronary heart disease	114
4.7.3	Cancer	119
4.7.4	Diabetes mellitus type 2	121
4.7.5	Adequate intake	121
<hr/>		
4.8	Comparison with other reports on dietary reference intakes	123
<hr/>		
	References	124

Table 4.1 Dietary reference intakes for fats and fatty acids.

nutrient	group	adequate intake		safe upper level of intake	
		criterion ^a	value	criterion	value
linolic acid	0 to 6 months	breastfeed	0.6 g/[kg.d]	-	-
	≥ 6 months	deficiency diseases	2 energy%	-	-
	pregnancy and lactation	factorial method	2.5 energy%	-	-
alfalinoic acid	0 to 6 months	breastfeed	0.08 g/[kg.d]	-	-
	≥ 6 months	coronary heartdisease	1 energy%	-	-
docosahexaic acid	0 to 6 months	breastfeed	0.02 g/[kg.d]	-	-
n-3 fatty acids in fish	6 months to 19 years	interpolation between	0.15-0.2 g/d	-	-
	≥ 19 years	infants and young adults	0.2 g/d	-	-
arachidonic acid	0 to 6 months	breastfeed	0.04 g/[kg.d]	-	-
	all groups	-	-	no increased risk of cancer	12 energy%
polyunsaturated fatty acids	≥ 4 years & desirable body weight	coronary heart disease ^b	8-38 energy%	-	-
	≥ 4 years & overweight or unwanted increase in body weight	coronary heart disease	8-28/33 energy%	-	-
saturated fatty acids	0 to 6 months	breastfeed	25 energy%	-	-
	6 to 12 months	coronary heart disease	as low as possibl	gradual decrease	20 energy%
	1 to 4 years	coronary heart disease	as low as possible	gradual decrease	15 energy%
	≥ 4 years	coronary heart disease	as low as possible	10th percentile of intake	10 energy%
trans fatty acids	all groups	coronary heart disease	as low as possible	10th percentile of intake	1 energy%
total fat	0 to 6 months	breastfeed	45-50 energy%	-	-
	6 to 11 months	gradual decrease	40 energy%	-	-
	1-3 years	gradual decrease	25-40 energy%	coronary heart disease	40 energy%
	≥ 4 years & desirable body weight	coronary heart disease	20-40 energy%	coronary heart disease	40 energy%
	≥ 4 years & overweight or unwanted increase in body weight	coronary heart disease	20-30/35 energy%	coronary heart disease	30/35 energy%

^a 'coronary heart disease' should be read as 'coronary heart disease or risk factor for coronary heart disease'.

^b The area of adequate intake of *cis* unsaturated fatty acids is not based on study results concerning these fatty acids, but calculated based on the dietary reference intakes of fats, saturated fatty acids, and *trans* fatty acids.

4.1 Introduction

The Committee evaluated the fatty acid requirement on a group-by-group basis. They distinguished between polyunsaturated fatty acids (with particular emphasis on linoleic acid, alpha-linolenic acid and n-3 fatty acids present in fish), monounsaturated fatty acids, saturated fatty acids and *trans* fatty acids. They also deal with the total fat requirement. The current level of knowledge is insufficient to allow dietary reference intakes to be drawn up for each individual fatty acid.

4.1.1 Nomenclature and occurrence

Dietary fat mainly consists of triglycerides, which are compounds of glycerol and fatty acids. Fatty acids can be saturated or unsaturated. Unsaturated fatty acids contain one or more double bonds between carbon atoms. The number of double bonds determines whether the fatty acid in question is monounsaturated or polyunsaturated. There are two types of double bond, the *cis* form and the *trans* form.

Table 4.2 covers those fatty acids that are most important within the context of this recommendation, together with their full names and abbreviated designations. In the abbreviated designation, the number that follows the C indicates the number of carbon atoms while the number that follows the colon indicates the number of double bonds.

Table 4.2 Some well-known dietary fatty acids.

name	abbreviated designation ^a
lauric acid	C12:0
myristic acid	C14:0
palmitic acid	C16:0
stearic acid	C18:0
oleic acid	C18:1 n-9 (Δ 9)
linoleic acid	C18:2 n-6 (Δ 9, 12)
alpha-linolenic acid	C18:3 n-3 (Δ 9, 12, 15)
arachidonic acid	C20:4 n-6 (Δ 5, 8, 11, 14)
eicosapentaenoic acid (EPA)	C20:5 n-3 (Δ 5, 8, 11, 14, 17)
docosahexaenoic acid (DHA)	C22:6 n-3 (Δ 4, 7, 10, 13, 16, 19)
elaidic acid	<i>trans</i> - C18:1 n-9 (Δ 9)
vaccenic acid	<i>trans</i> -C18:1 n-7 (Δ 11)

^a See description in the text.

Fatty acids consist of a carbon chain with a methyl group at one end and a carboxyl group at the other. The figure that follows the letter 'n' designates the position of the first double bond relative to the molecule's methyl group. The Greek letter 'ω' is sometimes used instead of the letter 'n'. In chemistry, the position of the double bonds relative to the molecule's carboxyl group is usually designated by the Greek letter 'Δ'.

Naturally occurring fatty acids generally have a *cis* configuration. Vegetable oils are generally rich in unsaturated fatty acids, such as oleic acid and linoleic acid. Hard vegetable fats such as palm oil, palm kernel oil and coconut fat are rich in saturated fatty acids, such as lauric acid, myristic acid and palmitic acid. Animal fat contains large amounts of stearic acid and palmitic acid. In addition, it is relatively rich in oleic acid. Bacteria in the digestive systems of ruminants are capable of converting *cis* fatty acids to *trans* fatty acids. As a result, some of the fatty acids in dairy products, as well as those in beef and mutton, have the *trans* configuration. The vaccenic acid contained in these products occurs primarily as the *trans* form. *Trans* fatty acids are also created during the industrial hardening of oils. In addition to *trans*-elaidic acid, these products generally contain a wide range of other *trans* fatty acids. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are primarily found in fatty fish. On average, in terms of weight, 20-25% of fish oil is eicosapentaenoic acid and 8-20% is docosahexaenoic acid (Wat98). Accordingly, these fatty acids are also designated as fish-oil fatty acids.

4.1.2 Terminology

This recommendation makes use of the following terminological conventions:

- The designations *cis* and *trans* and the specification of the location of the first double bond (n-3, n-6, etc.) are reserved for unsaturated fatty acids. When it uses these designations, the Committee will omit the term 'unsaturated'.
- In those instances where the Committee makes no specific mention of the configuration of an unsaturated fatty acid, it is referring to fatty acids with the *cis* configuration. Thus specific mention is only made of the configuration when the Committee is dealing with *trans* fatty acids.
- The Committee refers to blood samples taken from individuals in the post-absorptive state (who have had a zero energy intake – either in the form of food or drink – for at least eight hours), as 'fasting blood'. It refers to blood samples taken after meals as 'postprandial blood'.

4.1.3 Physiological significance

Virtually all of the tissues in the human body can use fatty acids as a source of energy. The exceptions are red blood cells and the central nervous system. In addition, fat is essential for the absorption, transport and storage of lipid-soluble vitamins. If the energy intake exceeds the requirement then the surplus energy is stored in the form of body fat. Subcutaneous adipose tissue is not merely an energy store, it also has an important role in terms of insulation. Adipose tissue is also located in areas where it can protect delicate organs from the effects of impacts, like the fat deposits around the kidneys for example.

The body requires linoleic acid and alpha-linolenic acid, but it cannot make them itself. This is why they are described as 'essential'. Symptoms of deficiency have only been described in individuals on a fat-free diet, in patients on an inadequate parenteral nutrition and in individuals with protein-energy malnutrition or with poor fat absorption. The body is not able to convert n-6 fatty acids (linoleic acid and its conversion products) to n-3 fatty acids (alpha-linolenic acid and its conversion products). It is similarly unable to convert n-3 fatty acids to n-6 fatty acids. However, it is able to use these essential fatty acids to form various other polyunsaturated fatty acids, such as arachidonic acid, eicosapentaenoic acid and docosahexaenoic acid (table 4.3). These phospholipids are vital constituents of the phospholipids in cell membranes. As a result, they are also involved in the action of hormones, proteins and enzymes. The body also uses these fatty acids in the synthesis of eicosanoids, hormone-like compounds that play a vital role

Table 4.3 Some fatty acid conversions and associated enzymes (Kee98).

non-essential fatty acids n-9 fatty acids	(semi-)essential fatty acids		enzymes involved in the conversion
	n-6 fatty acids	n-3 fatty acids	
C18:1 n-9 oleic acid	C18:2 n-6 linoleic acid	C18:3 n-3 alpha-linolenic acid	
↓	↓	↓	δ 6-desaturase elongase δ 5-desaturase
C20:3 n-9 mead acid	C20:4 n-6 arachidonic acid	C20:5 n-3 eicosapentaenoic acid	
		↓	elongase δ 6-desaturase β-oxidation
		C22:6 n-3 docosahexaenoic acid	

in many processes within the body. Under certain circumstances, insufficient amounts of essential fatty acids are converted to other polyunsaturated fatty acids. This means that a given level of intake is essential. For this reason, these are sometimes referred to as semi-essential fatty acids.

4.1.4 *Influence on the development of chronic diseases*

Later in this chapter, the Committee describes the results of studies into the effect of fatty acid intake and fat intake on the development of coronary heart disease, cancer and type 2 diabetes mellitus. In terms of the effect on body weight (obesity), the Committee restricts itself to total fat intake, since there is no evidence that the composition of dietary fat plays any part in this. Both body weight and the fat content of the diet are risk factors for chronic diseases. This was taken into account when investigating the effect of the fat content of the diet on the development of chronic disease. In addition to intervention studies in which body weight was kept constant (by providing carefully tailored amounts of nutrients), researchers also used intervention studies in which body weight was not kept constant (food supplied *ad libitum*). Since the composition of the diet in terms of fatty acids has no effect on body weight, the Committee has based its judgements (with regard to specific fatty acids or fatty acid groups) on intervention studies in which both the fat content of the diet and body weight were kept constant.

In evaluating the influence of fats on the development of cancer, the Committee has based its judgement on the literature review carried out by the World Cancer Research Fund (WCRF97), in addition to several recent review articles (Bra99, Zoc01). The Committee has restricted itself to cancers of the breast, colon, rectum and prostate, since these are particularly common and because dietary factors may play a major part in their development.

The Committee does not base its views purely on studies that use morbidity or mortality as result criteria. It also uses studies into the effects of risk factors for chronic disease (see section 1.4.2). The risk factors for coronary heart disease that are mentioned in this recommendation are depicted in table 4.4. The Committee takes the view that the ratio of the concentrations of total cholesterol and HDL cholesterol in the blood are the most important predictive factors for coronary heart disease. Although it is probably an equally good indicator, the ratio between LDL cholesterol and HDL cholesterol is not as commonly used. The reason is that LDL cholesterol is more difficult to measure than total cholesterol (CBO98, GR00, Kan92).

Table 4.4 Risk factors and intermediate endpoints for coronary heart diseases, mentioned in this chapter.

	type of study of which the results do (+) or do not (-) suggest a relationship between the factor and the incidence of the disease ^a			effect of an increase of the factor - or of the presence of the factor - on the incidence of the disease
	intervention study	prospective cohort study	case control study	
<i>factors in the blood, fasting:</i>				
HDL cholesterol concentration	+	+	+	↓
LDL cholesterol concentration ^b	+	+	+	↑
total cholesterol concentration ^b	+	+	+	↑
ratio between total and HDL cholesterol concentrations ^b	+	+	+	↑
lipoprotein a-concentration	-	+	+	↑
triglyceride concentration	-	+	+	↑
factor VII-activity	-	+	+	↑
fibrinogene concentration	-	+	+	↑
<i>factors in the blood, postprandial:</i>				
triglyceride concentration	-	-	+	↑
factor VII-activity	-	-	-	↑
fibrinogene concentration	-	-	-	↑
clotting of blood platelets	+	+	+	↑
blood pressure	+	+	+	↑
arterial flexibility	?	?	+	↓
body weight	-	+	+	↑
arhythmia	-	-	+	↑
diabetes mellitus type 2	-	+	+	↑

^a The '+' and '-' signs in the table do not denote whether or not there is a positive or negative association; the direction of the association is denoted in the utter right column.

^b The blood concentrations of HDL, LDL, and total cholesterol are usually determined in fasting blood samples; meals do, however, influence these concentrations to a limited extent only.

4.1.5 *Factors that influence requirement*

Dietary factors

New-born babies take up about 90% of the fat in human milk and in vegetable oils. During this period of life, less fat is absorbed from cow's milk. In individuals aged one year and above, fat absorption exceeds 95%.

The importance of the ratio between n-6 and n-3 fatty acids in the diet has yet to be convincingly demonstrated. It is possible that the requirement for n-6 fatty acids increases when there is a high intake of alpha-linolenic acid. Linoleic acid and alpha-linolenic acid compete for the binding site of the enzyme δ 6-desaturase (table 4.3). Alpha-linolenic acid has a higher affinity for this enzyme than does linoleic acid. It is therefore likely that a high alpha-linolenic acid intake would reduce the conversion of linoleic acid to arachidonic acid. The results obtained from one study indicate the opposite effect. A diet in which linoleic acid constituted five percent of total energy intake resulted in 19% of the alpha-linolenic acid being converted. However, when linoleic acid constituted nine percent of total energy intake, the corresponding conversion figure was 11% (Emk92). In 1994, a expert committee of the Food and Agricultural Organisation stated that the intake of n-6 fatty acids should be at least five times as high, but no more than ten times as high, as the intake of n-3 fatty acids (FAO94). On the basis of Emken's results, the Committee assumes in the present recommendation that the ratio between the linoleic acid and alpha-linolenic acid contents of the diet should not exceed a value of ten. According to the Committee, however, no indications of adverse health effects have been associated with a low ratio for linoleic acid and alpha-linolenic acid intake. Although there is no lower limit, the Committee has set an upper limit for this ratio.

According to this recommendation, an adequate intake of linoleic acid for babies from birth up to the age of five months is 7.5 times as high as that of alpha-linolenic acid (0.6 and 0.08 grams per kilogram per day respectively). An adequate intake of linoleic acid for the age groups of 6 months and above, however, is only twice as high as that of alpha-linolenic acid. The latter ratio is considerably lower than the FAO's lower limit. The Committee nevertheless takes the view that this will not lead to health problems.

The results of experiments in animals show that *trans* fatty acids can influence the metabolism of essential fatty acids. It was claimed that this effect only occurs when a high intake of *trans* fatty acids is combined with a low intake of essential fatty acids (BNF95).

When setting the dietary reference intakes for unsaturated fatty acids, the Committee assumes that there is an adequate intake of antioxidants such as vitamin E.

Physical activity

The results of short-term studies indicate that physical activity produces increased lipid oxidation (Ast97, Mar93, Sch97b, Tre95). One study showed that while the fat content of the diet had an effect on the body weight of inactive individuals, it had no effect on that of active individuals (Lis97). One study (on Swedish men) showed that a six-week long increase in physical activity reduced the concentrations of palmitic acid, linoleic acid and n-6 fatty acids in the phospholipids of skeletal muscles, while the concentration of oleic acid rose (And98). The Committee takes the view that these research results do not indicate a need to differentiate dietary reference intakes for individuals with different levels of physical activity.

4.2 Polyunsaturated fatty acids

4.2.1 *Deficiency symptoms*

The body needs linoleic acid and alpha-linolenic acid, but cannot synthesize these fatty acids. This is why these substances are referred to as essential fatty acids (see section 4.1.2). Premature babies also require docosahexaenoic acid and arachidonic acid.

Linoleic acid

In humans, linoleic acid deficiency leads to retarded growth and skin defects, such as a dry, scaly skin with a thickened keratinous layer (Han63). In establishing the amount of linoleic acid that is required to prevent deficiency, the Committee used the triene/tetraene ratio in fasting blood, a biochemical parameter for nutritional status (see section 1.4.3). This is the ratio of mead acid, a triple unsaturated fatty acid, and arachidonic acid, a quadruple unsaturated fatty acid. The body makes mead acid from oleic acid and arachidonic acid from linoleic acid (table 4.3). Adults are considered to have an adequate essential fatty acid status if the triene/tetraene ratio is less than 0.2 (Moh63). In order to achieve this value, the linoleic acid intake should be at least one percent of total energy intake (WCMV94). The Committee employs a one-hundred-percent safety margin, stating that a linoleic acid consumption of two percent of total energy intake is sufficient to prevent deficiency in adults.

Alpha-linolenic acid

There is some discussion concerning the symptoms of alpha-linolenic acid deficiency. Observations of human subjects, together with the results of experiments in animals,

indicate learning disorders, anomalous electroretinograms and reduced visual acuity (And89). Since deficiency symptoms have seldom been observed, it is only possible to make a rough estimate of the requirement for alpha-linolenic acid. On the basis of European data, the European Commission's Scientific Committee for Food concluded that an intake of 0.2 percent of total energy intake would probably not result in deficiency symptoms. They stated that in the case of adults, allowing a safety margin, an intake of half a percent of total energy intake would be sufficient to prevent deficiency symptoms (WCMV94). The Committee supports this opinion.

Docosahexaenoic acid and arachidonic acid

Premature babies are given supplementary docosahexaenoic acid and arachidonic acid in order to improve their visual acuity (Inn91, Nut98). It is quite likely that only docosahexaenoic acid is effective in this regard. However, arachidonic acid is required to prevent both growth retardation and a reduction of the concentration of arachidonic acid in the blood (Car92, Car93, Car96a, Car96b, For96, Mak95, Mon96).

The significance of these fatty acids for full-term babies is unknown (Inn99, Luc99, Mak96). However, both fatty acids are known to occur in human milk (Hel98, Luu94, Ron92). After birth, the concentration of docosahexaenoic acid in the blood falls. This reduction is more pronounced in women who are breastfeeding an infant (Ott00). As lactation proceeds, there is a gradual reduction in the concentration of docosahexaenoic acid in human milk (Luu94).

4.2.2 *Coronary heart disease*

Polyunsaturated fatty acids and linoleic acid

Four long-term intervention studies provide information about the effect of the fatty acid composition of the diet on the development of coronary heart disease (table 4.5). In those studies, while total fat consumption remained unchanged, animal fats were replaced by vegetable oils. In three studies, intervention reduced the risk of coronary heart disease (Day69, Ler70, Tur79). No such effect was seen in the fourth study (MRC68).

The Committee concluded from this intervention study that an improvement in the fatty acid composition of the diet reduces the risk of coronary heart disease. This might be due to an increase in the intake of specific polyunsaturated fatty acids. All interventions lead to an increase in the intake of linoleic acid. This was probably accompanied by a rise in the intake of alpha-linolenic acid (various types of vegetable oil, including soya oil, contain relatively high levels of alpha-linolenic acid). However the

Table 4.5 Intervention study into the effect of replacing animal fats with vegetable oils on coronary heart disease.

publication	Tur79	Day69	Ler70	MRC68
study question	primary prevention	primary plus secondary prevention	secondary prevention	secondary prevention
study group (number of subjects in intervention or control groups)	mentally ill males (444 and 478 respectively)	veterans, of whom about 30% had coronary symptoms at the start of the study (424 and 422 respectively)	heart patients (206 and 206 respectively)	heart patients (199 and 194 respectively)
study design	cross-over ^a	parallel ^b	parallel	parallel
duration of intervention	2 x 6 years	8 years	5 years (11 years) ^c	2 to 6.75 years
type of intervention	special diet	special diet	information	information ^d
type of oil	soya oil	various types including maize, soya, safflower and cotton seed oil	not described	soya oil
study results	the intervention reduces the risk of both fatal and severe non-fatal coronary heart disease by 67% ^e	the intervention reduced the risk of cardiovascular disease in general by 31% ^f	the intervention reduced the risk of a fatal myocardial infarction by 44%	the intervention had no effect on the risk of coronary heart disease

^a One institution provided a control diet for a period of six years, after which it provided the intervention diet for a further six years. In another institution these diets were provided in the reverse order. Thirty six percent of the participants received both the intervention and control diets.

^b In studies with a parallel design, individuals receiving the intervention diet are compared with individuals receiving the control diet.

^c Dietary information was provided during the first five years. In this period, the composition of the diet was evaluated and biochemical and clinical parameters were determined. Follow-up continued six years after the intervention had stopped.

^d During (a part of) this study, the information provided to the 174 participants aimed not only on replacing animal fats with vegetable oils, but also on weight reduction.

^e Because of the possible effects of medication on coronary heart diseases, modest deviations in the electrocardiogram have not been taken into account.

^f The intervention had no demonstrable influence on specific disorders such as myocardial infarction. The effect of the intervention did not differ between persons with and without heart complaints at the start of the study.

protective effect may also result from the reduction in the intake of saturated fatty acids or of *trans* fatty acids.

Norwegian researchers compared the effect on cardiovascular diseases of consuming 10 ml of linseed oil per day (rich in alpha-linolenic acid) with the effect of consuming 10 ml of sunflower oil per day (rich in linoleic acid) (Nat68)*. The intervention period was one year. There were no differences between the two

* Sunflower oil contains 63% linoleic acid and 1.4% alpha-linolenic acid, while linseed oil contains 15% linoleic acid and 55% alpha-linolenic acid. Both oils contain 19% oleic acid.

interventions, except in the small sub-group of men already suffering from angina pectoris prior to the start of the study (about 3% of the test subjects). In this subgroup, sunflower oil gave a lower risk of suffering a cardiac infarction than did linseed oil. However, since the researchers did not collect any information about the participants' dietary pattern, their results provide little insight into the effect of fatty acid composition on coronary heart disease.

The total intake of polyunsaturated fatty acids shows a marked linear relationship with the intake of linoleic acid. There is a less well pronounced relationship between the total intake of polyunsaturated fatty acids and the intake of other specific polyunsaturated fatty acids (based on Hul99). If the results of observational studies indicate that polyunsaturated fatty acids influence the risk of coronary heart disease, this is primarily related to the effect of linoleic acid. The Committee nevertheless takes the view that the possibility cannot be eliminated that another fatty acid, for example alpha-linolenic acid, is responsible for such research results.

Four out of thirteen prospective cohort studies revealed a protective effect of polyunsaturated fatty acids on coronary heart disease. No evidence for this was found in the remaining nine studies (Wil98a). In three studies, it was not possible to establish a relationship between linoleic acid and coronary heart disease (Asc96, Dol92, Pie97). Usually these analyses do not include a correction for the intake of other types of fatty acid. In a study carried out by Pietinen *et al.*, corrections were made for factors such as levels of intake of saturated, monounsaturated fatty acids and *trans* fatty acids (Pie97). Hu *et al.* also corrected their analyses for the intake of other fatty acid groups. They estimated that the replacement of saturated fatty acids equivalent to five percent of total energy intake with unsaturated fatty acids reduces the risk of coronary heart disease by 46% (Hu97).

The iso-energetic replacement of saturated fatty acids with polyunsaturated fatty acids reduces the concentrations of total cholesterol and LDL cholesterol in fasting blood (both estimated at -0.05 mmol/l per exchanged percentage of total energy intake), while the concentrations of HDL cholesterol and triglycerides remain unchanged. The concentrations of total cholesterol and LDL cholesterol may also decline a little if monounsaturated fatty acids are replaced with polyunsaturated fatty acids (based on Men92). Compared to saturated fatty acids, unsaturated fatty acids reduce factor VII activity in fasting blood (Mar98). There is no evidence that specific polyunsaturated fatty acids differ from one another in this respect (Mar98). In addition, the replacement of saturated fatty acids with polyunsaturated fatty acids reduces the tendency of blood platelets to adhere to one another (Hor73). Taking linoleic acid probably has no effect on blood pressure (Mor94).

The Committee concludes that the risk of coronary heart disease can be reduced by replacing saturated fatty acids with polyunsaturated fatty acids. While this effect is probably due to linoleic acid, alpha-linolenic acid could also account for these findings.

Alpha-linolenic acid

The studies described below have attempted to determine whether taking alpha-linolenic acid has any effect on the development of coronary heart disease.

The Lyon Diet Heart Study is a French study of cardiac patients, in which dietary guidelines aimed at the realization of a Mediterranean dietary pattern in the intervention group. The control group was given the standard information concerning healthy eating habits (Lor94, Lor99). One result of the intervention was that patients had a considerably higher alpha-linolenic acid intake and a slightly lower intake of linoleic acid and polyunsaturated fatty acids*. The patients were followed up over a five-year period. The intervention was found to reduce the risk of myocardial infarction and other severe cardiac problems by almost 70%. If moderate cardiac problems were also included in the analysis then the reduction in morbidity was almost 50%. Alpha-linolenic acid was the only fatty acid in which a higher plasma concentration was associated with a more favourable disease course. No definitive conclusions about alpha-linolenic acid can be drawn on the basis of the results of this study, however, since the intervention had many other effects on the diet. These included increased intakes of oleic acid, dietary fibre, vegetables and fruit, and a reduced cholesterol intake.

The results of two American prospective cohort studies show that an increase in alpha-linolenic acid as a percentage of the total energy intake offers some protection against myocardial infarcts and coronary mortality (Asc96, Dol92). Neither study included a correction for the intake of other fatty acids. However, this was done in two other prospective cohort studies. One Finnish study included a correction for the intake levels of saturated fatty acids, monounsaturated fatty acids and *trans* fatty acids (Pie97), while an American study corrected for the intake of saturated fatty acids and linoleic acid (Hu99). These two studies also provide evidence for a reduction in coronary mortality in association with a higher intake of alpha-linolenic acid. In three of the four cohort studies, the quintile classification used showed which level of intake had the most favourable effect. The average intake of individuals in the lowest and highest

* Dietary case history studies showed that the average intake of alpha-linolenic acid was 0.8 percent of total energy intake (1.8 g/d) in the experimental group and 0.3 percent of total energy intake (0.7 g/d) in the control group. The respective equivalent values for linoleic acid were 3.6 percent of total energy intake and 5.3 percent of total energy intake. In the blood of individuals from the experimental group, the concentrations of alpha-linolenic acid, eicosapentaenoic acid and oleic acid were higher than in individuals from the control group, while the concentrations of stearic acid, linoleic acid and arachidonic acid were lower (the respective values were +68%, +36%, +12%, -7%, -7%, -7%).

quintiles were 0.7 and 1.4 grams per day (Hu99), 0.9 and 2.5 grams per day (Pie97) and 0.4 and 1.0 percent of total energy intake (Dol92). Ascherio *et al.* provide no information concerning the distribution of intake (Asc96).

One indirect piece of evidence in support of the view that alpha-linolenic acid has a protective effect was obtained by means of an ecological analysis* (San93). Men from Crete have a lower risk of developing coronary heart disease than do men from Zutphen (the Netherlands). The Greek men's blood contained more alpha-linolenic acid than did that of the Dutch men.

As far as we are aware, the effects of alpha-linolenic acid on the concentrations of cholesterol fractions and tryglycerides in the blood (Har97a, Men92) and on blood pressure and blood clotting (Dec98, Kna97, Wen99) are the same as those of linoleic acid. Alpha-linolenic acid is claimed to increase arterial flexibility, thereby reducing the load on the heart (Nes97).

The Committee concludes that alpha-linolenic acid probably has a specific protective effect against coronary heart disease.

N-3 fatty acids from fish

An intervention study into the secondary prevention of coronary artery disease showed that eating fatty fish twice a week reduced cardiovascular mortality by 29% (Bur89). Since fish has additional ingredients, other than oil, the effect of eating fish cannot be directly attributed n-3 fatty acids from fish. However, this was possible in another intervention study. The GISSI study showed that the daily consumption of 0.3 grams of eicosapentaenoic acid plus 0.6 grams of docosahexaenoic acid plus 300 mg of vitamin E for a period of 3.5 years resulted in a 17% reduction in cardiovascular disease (GIS99).

Six prospective cohort studies showed that the weekly consumption of a portion of fish had a beneficial effect on cardiovascular mortality (Alb98, Asc95, Dav97, Gil96, Kro85, Kro95, She85). Generally, eating fish more often than this provided no additional protection. Two cohort studies failed to find any association whatsoever (Lap86, Mor95). In one of these studies, the dietary case history method (24 hour recall) was found to be unsuitable for estimating the intake of nutrients that are not eaten on a daily basis, which is the case with fish (Lap86). In a Finnish cohort study, an elevated consumption of n-3 fatty acids from fish for a period of six years was found to be associated with an elevated mortality resulting from cardiovascular disease (Pie97). In the course of this study, those subjects in the lowest intake quintile consumed an average of 0.2 grams of n-3 fatty acids from fish per day**. The authors take the view

* Comparisons between countries or regions (see section 1.4.2).

** In this study, n-3 fatty acids from fish were defined as n-3 polyunsaturated fatty acids containing 20 or 22 carbon atoms.

that this adverse effect can be attributed to the high mercury content of freshwater fish in Finland.

N-3 fatty acids from fish reduce the concentration of triglycerides in fasting blood. A daily intake of three to four grams produces a reduction of about 25% (Har97a). They also reduce the concentration of triglycerides in postprandial blood (Hor98, Roc00). N-3 fatty acids from fish produce a slight rise in the concentration of LDL cholesterol and HDL cholesterol in fasting blood. There is virtually no change in the total cholesterol content or in the ratio of total cholesterol to HDL cholesterol (Har97a). N-3 fatty acids from fish produce a slight decrease in systolic and diastolic blood pressure in hypertensive individuals. The values involved are 0.7 and 0.4 mmHg per gram, respectively (Mor93). In comparison to oleic acid and alpha-linolenic acid, n-3 fatty acids from fish appear to reduce the tendency of blood platelets to adhere to one another (Wen99). Furthermore, these fatty acids are claimed to have an anti-arrhythmic effect (Chr97, Chr99, Sin97, Sis97). The primary effect of n-3 fatty acids from fish is probably to reduce the risk of sudden cardiac arrest rather than to reduce the risk of heart diseases associated with atherosclerosis. The anti-arrhythmic effect is said to play an important part in this.

The Committee concludes that n-3 fatty acids from fish reduce the risk of coronary heart disease. The results of prospective cohort studies indicate that one portion of fish per week is sufficient to achieve this beneficial health effect. The weekly consumption of 70-280 grams of fatty fish is equivalent to an average daily consumption of 0.2 grams of n-3 fatty acids from fish (Dec98). According to the Committee, this is the adequate intake for adults.

4.2.3 *Cancer*

Polyunsaturated fatty acids and linoleic acid

In their survey article, Zock and Katan conclude that while a high intake of linoleic acid is probably not a major risk factor for breast, colorectal or prostate cancer, the possibility of a slight increase in risk cannot be excluded (Zoc98).

A meta-analysis of seven prospective cohort studies failed to show a connection between the intake of polyunsaturated fatty acids and the risk of breast cancer (Hun96). This was also the case for a meta-analysis of twelve controlled studies of patients (How90).

The results of two prospective cohort studies show that polyunsaturated fatty acids have a slightly protective effect against cancer of the colon (Bos94, Gio94). However, a third study of this type showed that there was a slight increase in risk (Gol94). The

results produced by seven controlled studies of patients, on the relationship with colorectal cancer, are far from clear (WCRF97).

The results of prospective cohort studies show that neither the intake of linoleic acid (Gio93) nor the concentration of linoleic acid in the blood (Gan94, Har97b) have any effect on the development of prostate cancer. The results of a fourth cohort study indicate that there is a protective effect (Sch99). In a controlled study of patients, the intake of unsaturated fatty-acids was not associated with prostate cancer (Kol88b).

The Committee takes the view that linoleic acid probably has no effect on the development of cancer.

Alpha-linolenic acid

The results of three prospective cohort studies indicate that a high concentration of alpha-linolenic acid in serum phospholipids and in adipose tissue (after correction for the concentrations of other fatty acids) increases the risk of prostate cancer (Gan94, Gio93, Har97b). On the basis of these study results it is impossible to quantify the level of intake that corresponds to an increased risk. In a Dutch prospective cohort study, however, a high intake level of alpha-linolenic acid was not associated with an increased risk of prostate cancer. In fact, the study in question indicated that there might be a protective effect. However, the association was not statistically significant (Sch99). The results of a controlled study of patients in Uruguay indicate that high intake levels of alpha-linolenic acid are associated with an heightened risk of prostate cancer (Sté00).

In the preceding section, the Committee pointed out that, on the basis of the results of the three prospective cohort studies indicating an increased risk, it was impossible to quantify the level of intake corresponding to such an increased risk. In order to obtain some understanding of the magnitude of the effect involved, the Committee has examined the average intake of alpha-linolenic acid and the distribution this intake (see table C8 in annex C). This data shows that only a small percentage of the adult men involved had an intake of one percent (or more) of total energy intake. Therefore, in the three prospective cohort studies, it is likely that the elevated risk groups had an intake that was at approximately this level.

Virtually no research has been carried out into the effect of alpha-linolenic acid intake on the development of other forms of cancer in humans (COMA98, WCRF97, Zoc01).

For the time being, the possibility that high intakes of alpha-linolenic acid increase the risk of prostate cancer cannot be excluded. However, the Committee feels that it will not be possible to draw any firm conclusions until further research has been carried out.

N-3 fatty acids from fish

Two prospective cohort studies found no relationship between the intake of fish (or fish oils) and the risk of developing breast cancer (Ton94, Wil87). A third study of this type showed that there was a slight protective effect (Vat90). The results of controlled studies with patients are also inconsistent (Hir95, Kle00, Sim98). In general, the results of animal experiments indicate that fish oil has a protective effect against the formation of breast tumours (Kar84, Ros94).

Two prospective cohort studies (Bos94, Wil90) and six controlled studies with patients (Dec99, Fer99, WCRF97) indicate that the consumption of fish has a slight protective effect against colorectal cancer. In two other cohort studies (Gio94, Gol94) and in eight controlled studies with patients (WCRF97) no such connection was found. There is no evidence that any protective effect produced by the consumption of fish oil can be attributed to the n-3 fatty acids found in fish (Zoc01).

The relationship between the intake of fish or fish oils and the risk of developing prostate cancer has yet to be fully investigated. No effect was found in two prospective cohort studies (Gio93, Sch99). The results of controlled studies with patients are inconsistent (Har97b, Nor99).

With regard to a possible protective effect by fish-oil fatty acids against breast cancer and colorectal cancer, the Committee believes that there is insufficient evidence to draw any conclusions

4.2.4 *Diabetes mellitus type 2*

The results of three prospective cohort studies indicate that the intake of polyunsaturated fatty acids has no effect on the development of diabetes mellitus type 2 (Col92, Fes95, Mar94). Prospective cohort studies and cross-sectional studies have produced inconsistent results (Fes99).

One prospective cohort study appeared to show that eating fish reduces the risk of diabetes (Fes91). Other studies of this type failed to demonstrate any such relationship (Fes99). Some, but not all intervention studies involving short-term intervention indicate that n-3 fatty acids from fish produce an improvement in insulin sensitivity (Sto96).

The Committee concluded that polyunsaturated fatty acids probably have no effect on the risk of developing diabetes mellitus type 2. There is insufficient data with which to draw conclusions about individual polyunsaturated fatty acids.

4.2.5 *Effects on the immune system*

An anti-inflammatory effect has been observed (Kel91) in individuals with an extremely high intake of alpha-linolenic acid (more than six percent of total energy intake), and in those whose n-3 fatty acids from fish consumption exceeds 1.5 percent of total energy intake (End89, Lee85).

The Committee takes the view that more research is required before conclusions can be drawn concerning any possible effects on the immune system.

4.2.6 *Adequate intake*

Infants from birth to five months

There is considerable variation in the total fat content of human milk. The Committee assumes that the average content is 42 grams per litre (Fom93). Ninety nine percent of this fat content consists of triglycerides (Fom93), 95% of which are fatty acids. Assuming a daily intake of human milk of equivalent to 0.15 litres per kilogram (see 1.4.5), the Committee estimates the daily fatty acid intake of breastfed infants to be 5.9 grams per kilogram.

The concentrations of essential fatty acids in human milk are partly dependent on the mother's intake of these fatty acids. The Committee bases its views on the average concentrations reported in studies of women in western countries.

Symptoms of linoleic acid deficiency have never been reported in breastfed infants. It has been estimated that, on average, the concentration of linoleic acid in the fatty acid fraction of human milk increases from approximately 9.3% in the first few weeks after birth to approximately 11.5% after six months (Luu94). The average value is 10% (Fom93, Luu94)*. At this concentration, the baby's average daily intake is 0.6 grams of linoleic acid per kilogram of body weight, or about five percent of total energy intake. This is an adequate intake for the age group from birth to five months.

The concentration of alpha-linolenic acid in the fatty acid fraction of human milk also increases. Starting at approximately 1.0% in the first weeks after birth, it reaches about 1.5% after six months. Put another way, it increases from 0.06 grams per kilogram after birth to 0.09 grams per kilogram after six months (Luu94). The adequate intake for infants from birth up to an age of five months is 0.08 grams per kilogram.

* In normal western dietary patterns, the linoleic acid content of the fatty acid fraction of human milk varies from 7% to 17%. The concentration was considerably higher in mothers with Vegan dietary habits (about 30%). The variation was caused by differences in the mother's intake of linoleic acid, which in turn produces differences in the composition of maternal adipose tissue (Fom93).

Immediately after birth, the concentration of docosahexaenoic acid in human milk is about 0.4%. It subsequently decreases gradually until, after six months, it reaches a level of approximately 0.2% (Luu94). The values correspond to an average daily docosahexaenoic acid intake of 0.02 grams per kilogram for new-born babies and of 0.01 grams per kilogram for infants aged six months. One week after birth, arachidonic acid constitutes approximately 0.6% of the total fatty acid content. As is the case with docosahexaenoic acid, this level halves within six months (Luu94). Thus the average daily intake of arachidonic acid in breastfed infants gradually decreases from 0.04 grams per kilogram to 0.02 grams per kilogram. It is not known whether the above-mentioned fatty acids are essential ingredients of the diet of full term infants. It has been shown, however, that fatty acids are important for premature infants. In view of this, the Committee has set an adequate intake that is equivalent to the average intake of breastfed infants. This amounts to 0.02 grams of docosahexaenoic acid per kilogram per day, and 0.04 grams of arachidonic acid, per kilogram per day.

Other age groups

For alpha-linolenic acid, the criterion for adequate intake is the protective effect against coronary heart disease. On the basis of data from intervention studies and prospective cohort studies, the Committee has provisionally set the adequate intake of alpha-linolenic acid for all remaining groups at one percent of total energy intake. This value conforms with the conclusions reached at a recently held workshop on n-3 fatty acids (Dec98). An important point here is the possible effect of alpha-linolenic acid on prostate cancer (see 4.2.3). The Committee points out that a lower intake is sufficient to prevent the occurrence of deficiency diseases.

On the basis of their protective effect against cardiovascular disease, the Committee has set the adequate intake of n-3 fatty acids from fish or adults at an average daily intake of 0.2 grams. This is equivalent to 70-280 grams of fatty fish per week. From birth up to an age of five months, babies receiving no other food than human milk consume on average approximately 0.15 grams of eicosapentaenoic acid plus docosahexaenoic acid per day. For infants aged six months and above, and for children and adolescents, the adequate intake of n-3 fatty acids from fish is 0.15 to 0.2 grams per day.

There is no evidence that linoleic acid has a specific effect on chronic diseases. For adults (as mentioned in section 4.2.1), a linoleic acid intake equivalent to at least two percent of total energy intake is sufficient to prevent symptoms of deficiency. The Committee considers that this level of intake is also adequate for infants aged from six to eleven months, toddlers, young children and adolescents.

Pregnancy and lactation

During pregnancy, about 600 grams of essential fatty acids are deposited in the tissues of the foetus and those of the mother. The amount of linoleic acid involved is five to ten times greater than the amount of alpha-linolenic acid (FAO94). Assuming a ratio of 7½ : 1, the amounts of linoleic acid and alpha-linolenic acid deposited during an 'average pregnancy' are 525 grams and 75 grams respectively. This is equivalent to 2.0 grams of linoleic acid and 0.3 grams of alpha-linolenic acid per day. The Committee has set the increase in the daily requirement to match these values. This is equivalent to an adequate linoleic acid intake of 2.5 percent of total energy intake. The Committee believes that the adequate intake of alpha-linolenic acid does not change during pregnancy*.

Women who are breastfeeding an infant lose an average of 0.5 grams of alpha-linolenic acid per day via the human milk. However, the Committee feels that an alpha-linolenic acid intake of one percent of total energy intake is sufficient, even during lactation. On average, breastfed infants receive 0.6 grams of linoleic acid per kilogram of body weight (see start of this section). This means that, on average, women who are breastfeeding an infant secrete 3.2 grams of linoleic acid per day. This additional requirement can be met by a diet containing an amount of linoleic acid equal to at least 2.5 percent of total energy intake.

As mentioned in section 4.2.1, after a woman has given birth, there is a fall in the concentration of docosahexaenoic acid in her plasma phospholipids. This reduction is more marked in women who are breastfeeding an infant than in women who formula-feed their babies. This indicates an increased requirement for n-3 fatty acids from fish during lactation. Women who are breastfeeding an infant can increase the concentration of docosahexaenoic acid in their blood by consuming fish oil (Hel98). The body can also synthesize docosahexaenoic acid from alpha-linolenic acid (see section 4.1.3, table 4.3). The extent to which women who are breastfeeding an infant are able to meet their docosahexaenoic acid requirement by increasing their intake of alpha-linolenic acid is not known. It is also not clear whether an improved docosahexaenoic acid status is actually better in terms of health. There is insufficient data available to determine an adequate intake.

4.2.7 *Tolerable upper intake level*

An extremely high intake of polyunsaturated fatty acids might conceivably cause side effects. This might include an increased risk of cancer, possibly as a result of radical

* The energy requirement is increased during pregnancy and lactation. Thus, in the case of alpha-linolenic acid, no change in the percentage of total energy intake will correspond to an increased intake in terms of grams per day.

formation. However, vegetable products which are naturally rich in polyunsaturated fatty acids also contain large quantities of vitamin E, which is said to counter radical formation (WCMV94).

The Committee feels that it would be inadvisable to consume large quantities of polyunsaturated fatty acids. However, there is very little reliable scientific data available on which to base a tolerable upper limit.

The population of Israel and some groups in Belgium consume an amount of linoleic acid that is equivalent to twelve percent of total energy intake. No adverse effects related to this dietary pattern have been found in these groups (Zoc98). Similarly, no short-term adverse effects were found in babies who had been given infant formula in which 60% of the total fat content was in the form of linoleic acid (Wid89). This is a NOAEL value* for acute effects produced by a high level of exposure.

For the time being, the possibility that alpha-linolenic acid increases the risk of prostate cancer cannot be excluded. However, as indicated in section 4.2.3, it is the Committee's view that there is insufficient scientific evidence to support the existence of this adverse effect.

A study (without a control group) was carried out into a group of 11 patients with familial hypercholesterolaemia, who were consumed n-3 fatty acids from fish over a six-month period. It was found that eight adolescents in this group suffered one (or two) nosebleeds during the intervention period. During the course of the study, the dose of n-3 fatty acids from fish was increased from one gram per day in the first month to five grams per day in the fifth and sixth months (Cla90). This is designated LOAEL**.

The Committee considers that there is insufficient data available for them to set tolerable upper intake levels for these individual fatty acids. They have set the tolerable upper limit for the total intake of polyunsaturated fatty acids at twelve percent of the total energy intake.

4.3 Monounsaturated fatty acids

4.3.1 Coronary heart disease

The Committee is not aware of any intervention studies into the influence of monounsaturated fatty acids on the development of coronary heart disease.

A survey article of prospective cohort studies refers to just one study result on monounsaturated fatty acids (Wil98a). It states that the Framingham study showed that young men with a high intake of fatty acids of this type had an increased risk of coronary heart disease (Pos91). In that study, the major source of monounsaturated

* NOAELs are *No Observed Adverse Effect Levels*, see section 1.2.4.

** LOAELs are *Lowest Observed Adverse Effect Levels*, see section 1.2.4.

fatty acids was meat. One Finnish prospective cohort study found no connection with the risk of coronary heart disease (Pie97). On the basis of the results of a third cohort study, it was estimated that the replacement of saturated fatty acids amounting to five percent of total energy intake with monounsaturated fatty acids produced a 31% reduction in the risk of coronary heart disease (Hu97).

A meta-analysis of intervention studies concluded that monounsaturated fatty acids produced a slightly more pronounced increase in the concentration of HDL cholesterol in the blood than do polyunsaturated fatty acids. However, they produce a slightly smaller reduction in the concentrations of LDL cholesterol and total cholesterol and of triglycerides (Men92). A recent intervention study demonstrated that while olive oil produces higher triglyceride concentrations in fasting and postprandial blood than do sunflower oil and canola oil*, but factor VII activity in postprandial blood is lower (Lar99). It is still unclear what effect monounsaturated fatty acids have on the concentration of fibrinogen in the blood (San97). Monounsaturated fatty acids probably have no effect whatsoever on blood pressure (Mor94).

The effects of monounsaturated fatty acids on the concentrations of lipids in fasting blood resemble those of polyunsaturated fatty acids. The Committee believes it to be likely that, compared to saturated fatty acids, monounsaturated fatty acids reduce the risk of atherosclerosis. However, the scientific evidence on monounsaturated fatty acids is less convincing than that for polyunsaturated fatty acids. Since there are no intervention studies with coronary artery disease as the end point. In addition, the results obtained with prospective studies are far from unequivocal. The Committee considers that the available data is insufficient for it to be able to draw up dietary reference intakes.

4.3.2 *Cancer*

Studies into the influence of monounsaturated fatty acids on the development of human cancer have produced divergent results. According to a combined analysis of the results of seven prospective cohort studies, monounsaturated fatty acids have no effect on the development of breast cancer (Hun96). A combined analysis of the results of twelve controlled studies of patients, however, indicates that postmenopausal women who consume these nutrients have a greater risk of developing breast cancer (How90). Conversely, the Dutch Cohort Study into nutrition and cancer found that monounsaturated fatty acids have a slightly protective effect against breast cancer (Bra93). Finally, data from some experimental animal studies and from observational

* The saturated fatty acid contents of olive oil, canola oil and sunflower oil are 15%, 8% and 12% respectively. The percentages for monounsaturated fatty acids are 78%, 63% and 25%, and those for polyunsaturated fatty acids are 7%, 30% and 62% (of which 1%, 10% and 1% respectively, consist of alpha-linolenic acid) (Lar99).

studies shows that olive oil's putative protective effect against breast cancer is not due to monounsaturated fatty acids (Zoc01).

One prospective cohort study found that monounsaturated fatty acids actually increase the risk of developing colorectal cancer (Wil90), while three similar studies could demonstrate no such association (Bos94, Gio94, Gol94). The results obtained from eight controlled studies of patients are mutually inconsistent (WCRF97).

According to two cohort studies, monounsaturated fatty acids have no influence on the risk of developing prostate cancer (Gio93, Sch99). The results obtained from eight controlled studies of patients are mutually inconsistent (WCRF97).

It is unclear whether or not the consumption of monounsaturated fatty acids influences the development of cancer.

4.3.3 *Diabetes mellitus type 2*

A review article on the effect of dietary fats on the development of diabetes mellitus type 2 showed that the results of prospective cohort studies are not consistent (Fes99). It reported that two studies of this type indicate the monounsaturated fatty acids have a risk-enhancing effect, while two other cohort studies found no association. Three cross-sectional studies showed that there was a higher insulin concentration in the fasting blood of subjects with a higher intake of monounsaturated fatty acids.

It is unclear what effect, if any, consuming monounsaturated fatty acids has on the development of diabetes mellitus type 2.

4.3.4 *Adequate intake*

The Committee considers that there is insufficient data available for them to set an adequate intake for monounsaturated fatty acids. However, they have concluded that monounsaturated fatty acids are a safe source of energy.

4.3.5 *Tolerable upper intake level*

No studies have shown adverse effects of high intake of monounsaturated fatty acids. For this reason, the Committee has not set a tolerable upper intake level.

4.4 **Total intake of monounsaturated fatty acids plus polyunsaturated fatty acids**

In the previous section, the Committee concluded that it was unable to set an adequate intake for monounsaturated fatty acids. In the rest of this chapter, the Committee

derives the dietary reference intakes for the total intake of fats (see section 4.7), for saturated fatty acids (see section 4.5) and for *trans* fatty acids (see section 4.6). If the total consumption of fatty acids is reduced in terms of the intake of saturated and *trans* fatty acids, this leaves unsaturated fatty acids with the *cis* configuration. Since both the dietary reference intakes for total fat and those for saturated and *trans* fatty acids focus on minimizing the risk of coronary heart disease, this is also the *de facto* criterion for the resulting dietary reference intakes for monounsaturated fatty acids plus polyunsaturated fatty acids.

4.4.1 Adequate intake range

The adequate intake range for monounsaturated fatty acids plus polyunsaturated fatty acids is calculated in table 4.6. The calculation shows that, given a total fat consumption of twenty percent of total energy intake, the intake of monounsaturated fatty acids plus polyunsaturated fatty acids equals no less than eight percent and no more than nineteen percent of total energy intake. At a fat consumption of 35% of total energy intake, the optimum intake of monounsaturated fatty acids plus polyunsaturated fatty acids is between 22% and 33% of total energy intake. In practice, the upper limits are slightly lower than this, since it is not possible to formulate a balanced diet that is entirely free of saturated and *trans* fatty acids.

Table 4.6 Calculation of the adequate intake zone for monounsaturated fatty acids plus polyunsaturated fatty acids.

dietary reference intakes for total fat (see section 4.7)	total fatty acid intake ^b	saturated fatty acids (see section 4.5)	<i>trans</i> fatty acids (see section 4.6)	total monounsaturated fatty acids plus poly- unsaturated fatty acids
20 lower limit of the adequate intake zone	19	(upper limit)	1 (upper limit)	8
	19	0 (theoretical lower limit)	0 (theoretical lower limit)	19 (theoretical upper limit)
40 (upper limit of the adequate intake zone for individuals with an ideal body weight)	38	10 (upper limit)	1 (upper limit)	27
	38	0 (theoretical lower limit)	0 (theoretical lower limit)	38 (theoretical upper limit)
30 or 35 (upper limit of the adequate intake zone for individuals who are overweight or who experience undesirable weight gains)	28 or 33	10 (upper limit)	1 (upper limit)	17 or 22
	28 or 33	0 (theoretical lower limit)	0 (theoretical lower limit)	28 or 33 (theoretical upper limit)

^b Total intake of fatty acids = 0.95 x total fat consumption.

^a Calculated as the total intake of fatty acids minus the intake of saturated and *trans* fatty acids.

^a The Committee takes the view that the intake of saturated and *trans* fatty acids should be as low as possible. The body has no physiological requirement for these fatty acids. For this reason, the theoretical lower intake limit is zero. In practice, however, a mixed diet will always contain saturated and *trans* fatty acids.

Since the intake of polyunsaturated fatty acids should be between three and twelve percent of total energy intake (see section 4.2), it is also possible to calculate upper and lower limits for the intake of monounsaturated fatty acids. When total fat consumption is 35 percent of total energy intake and there is a low intake of polyunsaturated fatty acids (three percent of total energy intake), the optimum intake of monounsaturated fatty acids varies from 19 to 30 percent of total energy intake. Where there is a maximum intake of polyunsaturated fatty acids (12% of total energy intake), the optimum intake of monounsaturated fatty acids is 10 to 21% of total energy intake. Here too, the indicated upper limits are not entirely feasible in practice, since a balanced diet will always contain saturated and *trans* fatty acids.

4.5 Saturated fatty acids

4.5.1 Coronary heart disease

Intervention studies into the effect of saturated fatty acids on the development of coronary heart disease are described in 4.2.2 and table 4.5. In those studies, while the fat content remained unchanged, animal fats were replaced by vegetable oils. Three studies indicate that saturated fatty acids increase the risk of coronary heart disease, both in healthy individuals and in cardiac patients (Day69, Ler70, Tur79). The fourth study found no such effect (MRC68).

The results of four prospective cohort studies indicate that saturated fatty acids increase the risk of coronary heart disease, however, ten similar studies showed no such association (Wil98a).

In general, there is an increase in the concentrations of total cholesterol and LDL cholesterol in fasting blood if unsaturated fatty acids in the diet are iso-energetically replaced by saturated fatty acids (Men92). Stearic acid (C18:0), however, has a neutral effect on LDL cholesterol. Since there is also a neutral effect on HDL cholesterol, the ratio between the concentrations of these two cholesterol fractions remains unchanged. Saturated fatty acids with short or medium length carbon chains (C6:0, C8:0 and C10:0) probably cause a slight reduction in total cholesterol, LDL cholesterol and HDL cholesterol relative to fatty acids with longer carbon chains. However, the effect on the ratio between total cholesterol and HDL cholesterol is virtually the same (Cat97, Men92, Tem97). The Committee concludes that, in terms of the ratio between the concentrations of total cholesterol and HDL cholesterol in the blood, there is no evidence in support of distinguishing between saturated fatty acids with carbon chains of different lengths. That ratio is considered to be the most important predictive factor for coronary heart disease (see also section 4.1.4).

It is unclear what effect saturated fatty acids have on the concentration of triglycerides in postprandial blood (Jac99). Saturated fatty acids probably have no effect whatsoever on blood pressure (Mor94). It is also unclear what effect saturated fatty acids have on the concentration of fibrinogen in the blood (San97). There is some evidence that individual fatty acids differ from one another in this regard (Men98). Compared to unsaturated fatty acids and carbohydrates, saturated fatty acids increase factor VII activity (Men98). In comparison to polyunsaturated fatty acids, saturated fatty acids increase the tendency of blood platelets to adhere to one another (Hor73).

The Committee concludes that, relative to unsaturated fatty acids, saturated fatty acids increase the risk of coronary heart disease as a result of their adverse effect on the ratio between the concentrations of total cholesterol and HDL cholesterol in fasting blood.

4.5.2 *Cancer*

Most prospective cohort studies into a possible relationship between the intake of saturated fatty acids and the risk of developing breast cancer have failed to demonstrate the existence of any such association (Hun96, Wil98a, Zoc01). The results of controlled studies of patients, on the other hand, show that saturated fatty acids increase the risk of breast cancer in postmenopausal women. No such association was found in younger women (How90).

The results of several cohort studies indicate that saturated fatty acids increase the risk of colorectal cancer (Wil90, Gol94). Other, similar studies showed no such association (Bos94, Gio94). In one study it appeared that these fatty acids actually offered some protection against colon cancer (Stem84). Fifteen different controlled studies of patients also produced mutually contradictory results (Fra99, WCRF97).

According to two cohort studies, there is no association between the intake of monounsaturated fatty acids and the risk of developing prostate cancer (Gio93, Sch99). The six controlled studies of patients that investigated this relationship produced mutually contradictory results (Sch99).

The Committee ascribes more value to evidence obtained from prospective cohort studies than to evidence obtained from controlled studies of patients. For this reason, it concludes that saturated fatty acids probably do not increase the risk of breast cancer. Neither do saturated fatty acids appear to affect the risk of prostate cancer or colorectal cancer.

4.5.3 *Diabetes mellitus type 2*

It is unclear whether there is a relationship between the intake of saturated fatty acids and the risk of diabetes (Fes99, Sto96). A summary of the results of a three-month-long intervention study has recently been published. In this study, a saturated fatty acid intake equal to eight percent of total energy intake was isoenergetically replaced with monounsaturated fatty acids (Ves99, Ves01). The results seem to suggest that saturated fatty acids reduce insulin sensitivity, but have no effect on insulin secretion. A possible explanation for this result is that an increased concentration of saturated fatty acids in cell membranes reduces the number of insulin receptors (Ves94).

The Committee feels that more research is required before conclusions can be drawn concerning the effect of saturated fatty acids on the development of diabetes mellitus type 2.

4.5.4 *Adequate intake*

Infants from birth to five months

The saturated fatty acids in human milk are equivalent to approximately 25% of total energy intake (NEVO table). According to the Committee, this is the adequate intake for infants from birth to five months.

Other groups

The human body is capable of synthesizing saturated fatty acids. Thus, to the best of our knowledge, it is not necessary to include any saturated fatty acids in the diet. Given this fact, the adequate intake could theoretically be set at zero percent of total energy intake. Saturated fatty acids increase the risk of coronary heart disease (see section 4.5.1). However nothing is known about the health effects of diets that contain no saturated fatty acids whatsoever. This is because a varied diet will always contain saturated fatty acids. On the basis of the above considerations, it is the Committee's view that the intake of saturated fatty acids should be as low as possible.

4.5.5 *Tolerable upper intake level*

The Committee has based the adult upper limit for saturated fatty acids on the lowest percentage of total energy intake that is currently feasible in the Netherlands. Data

obtained from the 1997-1998 Dutch Food Consumption Survey show that the consumption of the food groups meat, dairy products, eggs and fish results – dependent of the age group – in a average intake of saturated fatty acids between 5.5 and 7.5 percent of total energy intake. The tenth percentile of the total intake of saturated fatty acids is approximately ten percent of total energy intake (Hulshof KFAM unpublished data from the 1997-1998 Dutch Food Consumption Survey). On this basis, the Committee has set the tolerable upper intake level for saturated fatty acids at the level of the tenth percentile, i.e. at 10% of total energy intake.

For infants from birth to five months, the tolerable upper intake level is 25% of total energy intake, the same as adequate intake. The Committee advocates a gradual transition to 10% of total energy intake. For this reason, it has set the tolerable upper intake level for the 6 to 11 month age group at 20% of total energy intake, while the value for the group aged from 1 to 3 is 15% of total energy intake. The tolerable upper intake level for adolescents and for children aged four and above is the same as that for adults.

4.6 *Trans* fatty acids

4.6.1 *Coronary heart disease*

No intervention studies have been carried out to investigate the effect of *trans* fatty acids on the development of coronary heart disease. However, this relationship has been investigated in three prospective cohort studies. All three studies showed that *trans* fatty acids increase the risk of coronary mortality (Asc96, Hu97, Pie97).

If *cis* fatty acids equivalent to one percent of total energy intake are replaced by *trans* fatty acids with a single double bond, also equivalent to one percent of total energy intake, then the concentration of LDL cholesterol in fasting blood increases while that of HDL cholesterol falls. As a result, the ratio between the concentrations of LDL cholesterol and HDL cholesterol increases by 0.05 (Men98). In addition, *trans* fatty acids increase the concentrations of triglycerides and of lipoprotein Lp(a) in fasting blood (Asc99). Intervention studies indicate that *trans* fatty acids have no effect on blood pressure (Men91, Zoc93). Little is known about the effects of *trans* fatty acids on the coagulation of blood (Mar98).

Even less is known about the effects of polyunsaturated *trans* fatty acids on the development of coronary heart disease. The results of a recent study indicate that the effects of *trans* alpha-linolenic acid on the ratio between the concentrations of LDL cholesterol and HDL cholesterol in the blood are just as adverse as those of monounsaturated *trans* fatty acids, if not more so (Ver01).

The Committee concludes that *trans* fatty acids increase the risk of coronary heart disease by means of an adverse effect on the concentrations of lipids in the blood. This conclusion is mainly based on studies involving monounsaturated *trans* fatty acids. The effects of polyunsaturated *trans* fatty acids on the development of coronary heart disease are still too poorly understood.

4.6.2 *Diabetes mellitus type 2 and cancer*

The Committee is unaware of any studies into the relationship between the intake of *trans* fatty acids and the risk of developing diabetes. A few articles have been published on the relationship with cancer. Two prospective cohort studies into the association with breast cancer did not produce clear results (Hol00, Voo00). Two prospective cohort studies showed that there is no association between the intake of *trans* fatty acids and the risk of developing prostate cancer (Gio93, Sch99).

The Committee concludes that, in the absence of sufficient research data, it cannot make any statements about the role of *trans* fatty acids in the development of cancer and diabetes mellitus type 2.

4.6.3 *Adequate intake*

For the moment, there is no evidence to suggest that the human body has a requirement for *trans* fatty acids. *Trans* fatty acids increase the risk of coronary artery disease and may have adverse effects on the metabolism of essential fatty acids (see section 4.1.5). Using similar reasoning to that employed in the case of saturated fatty acids, the Committee feels that *trans* fatty acid intake should be kept as low as possible.

4.6.4 *Tolerable upper intake level*

Data obtained from the 1997-1998 Dutch Food Consumption Survey show that the consumption of the food groups meat, dairy products, eggs and fish results in a average intake of *trans* fatty acids of approximately 0.5 percent of total energy intake. Dependent on the age group involved, the tenth percentile of intake varies between 0.7% and 1.0% of total energy intake (table 4.7). On this basis, the Committee has set the tolerable upper intake level for *trans* fatty acids at one percent of total energy intake.

Table 4.7 Tenth percentile of the total intake of trans fatty acids and the intake of trans fatty acids via meat, dairy products, eggs and fish, per age group, expressed as a percentage of total energy intake (Hulshof KFAM, unpublished data from the 1997-1998 Dutch Food Consumption Survey).^a

age in years	tenth percentile of the total intake of <i>trans</i> fatty acids		intake of <i>trans</i> fatty acids via meat, dairy products, eggs and fish	
	M	F	M	F
1 to 3 years of age	0.7	0.7	0.5	0.5
4 to 8 years of age	0.8	0.8	0.4	0.4
9 to 13 years of age	1.0	1.0	0.4	0.4
14 to 18 years of age	0.9	0.9	0.4	0.4
19 to 50 years of age	0.8	0.8	0.5	0.5
51 to 70 years of age	0.8	0.8	0.5	0.5
> 70 years of age	0.8	0.9	0.4	0.5

^a M = boys and men; F = girls and women

4.7 Total fat

4.7.1 Overweight

Remarks concerning methodology

Observational studies into the relationship between the fat content of the diet and individuals becoming overweight have various intrinsic problems in the area of methodology. For example, overweight individuals usually underestimate their energy intake (Lic92, Pre96) and their fat intake (Hei95). Due to their strong mutual association (Hei95), it is difficult to investigate fat intake and energy intake independently of one another. In addition, observational studies within populations are hindered by the often small variation in fat consumption between individuals.

Intervention studies have different problems in terms of methodology. Different study designs are required to determine whether body weight is influenced by the fat content of the diet. If this effect is due to physiological mechanisms, then this can be demonstrated using studies in which one macronutrient is iso-energetically replaced with another. However, weight regulation can also be affected by changes in energy intake. In order to investigate this possibility, it is necessary to provide food *ad libitum*, i.e. with no attempt to influence energy intake. In a study with this type of design, it is very difficult to evaluate dietary compliance. Another limitation associated with the methodology of studies using the *ad libitum* provision of food is that it is impossible to

use 'blinding' in this type of study. This is because the fat content of a diet has a clearly noticeable effect in terms of taste.

Research results

The results of various ecological* and cross-sectional studies show a positive relationship between the fat content of the diet and body weight (Gol97, Lis95, Sha96). Prospective cohort studies have failed to produce any clear findings (Col90, Hei95, Kan95, Kle92, Lis97, Ris91).

In the next two paragraphs, the Committee describes the results of intervention studies in which fats were iso-energetically replaced with other macronutrients. The first paragraph deals with studies in which energy intake is equal to requirement, while the second paragraph covers research into the effects of overconsumption.

For individuals who are in energy balance, if the fat content of their diet changes then their 24-hour energy consumption generally remains the same (Abb90, Ast94, Hil91, Sch97a). Individuals whose eating behaviour is focused on slimming appear to represent an exception to this rule. If these individuals' energy intake is equivalent to requirement, high-fat diets would result in lower 24-hour energy consumption than would low-fat diets (Ver94, Ver96).

If energy intake exceeds the requirement, then a high-fat diet would result in a lower 24-hour energy consumption than would a high-carbohydrate diet (Hor95)**. One possible explanation for this is that the storage of fat requires less energy than the conversion and storage of carbohydrates in the form of body fat (Fla85). Thus, in the case of an excessive energy intake, high-fat diets should produce a greater increase in weight than low-fat diets.

In the following paragraph, the Committee describes the effects of the fat content of the diet on energy intake and on body weight. This relates to intervention studies involving the *ad libitum* provision of food, in which the test subjects' determine their own energy intake.

Intervention studies in which food is supplied *ad libitum* have shown that high-fat food results in an increased energy intake. Astrup *et al.* carried out a meta-analysis on the results of ten controlled studies involving an intervention period of at least two months. If the fat content of the diet was reduced by an average of ten percent of total energy intake then the energy intake fell by approximately one MJ per day (Ast00).

* Comparisons between countries or regions (see section 1.4.2).

** In the intervention study in question, 16 individuals consumed one and a half times their energy requirement over two 14-day periods. In one of these periods, the excess feeding (0.5 times the energy requirement) was purely in the form of fats, in the other period it was purely in the form of carbohydrates. The composition of the remaining part of the diet (one time the energy requirement) took the form of the usual diet of the individual in question.

In various meta-analyses of intervention studies involving the *ad libitum* provision of food, estimates were made of the effect of the diet's fat content on body weight (Ast00, Bra98, Wil98b, Yu99). Bray and Popkin estimate that a reduction of the fat content equal to ten percent of the total energy intake results in a weight reduction of 16 grams per day (Bra98). In doing so, they make the implicit assumption that body weight continues to fall for the duration of the low-fat diet. Yu-Poth *et al.* did not investigate the significance of the duration of intervention. They estimate that reducing the fat content of the diet by 10% of total energy intake reduces body weight by 2.8 kilograms (Yu99). In the previously discussed meta-analysis by Astrup *et al.*, reducing the fat content of the diet by 10% of total energy intake produced an average weight loss of 2.6 or 3.2 kilograms (depending on the regression analysis model used) (figure 4.1).

In the meta-analysis conducted by Astrup *et al.*, weight loss was unrelated to the duration of the intervention, however, it was related to average body weight at the start of the study. In studies involving overweight individuals, the average weight loss was greater than in studies involving individuals with a normal body weight.

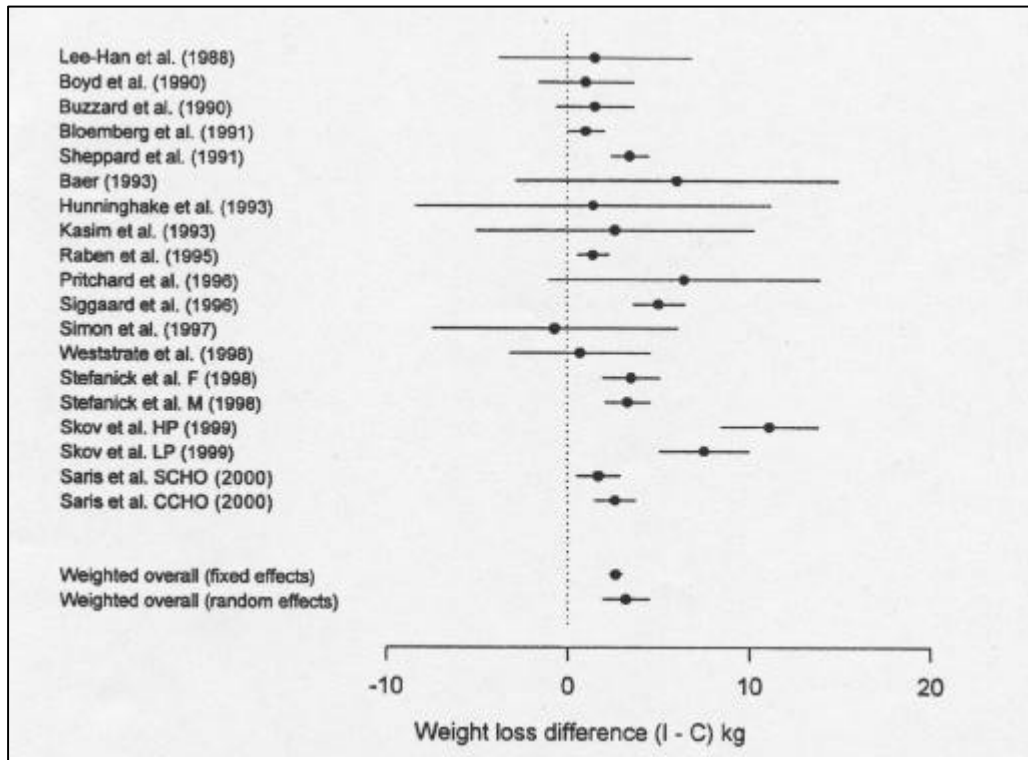


Figure 4.1 Differences in the reduction of body weight (changes in the 'I' intervention group minus those in the 'C' control group) at 95% confidence intervals in the 19 studies included in the meta-analysis conducted by Astrup *et al.* and the weighted averages and 95% confidence intervals of the meta-analyses, based on fixed effects and random effects (figure copied from Ast00).

In general, a low-fat diet has a lower energy density (Sar00)*. The effect on body weight may come about via this reduction in energy density (Stu95).

A reduction in the fat content of the diet can be accompanied by an increase in the consumption of vegetables, fruit and dietary fibre. The possibility cannot be excluded that such a change in dietary pattern (independent of any changes in fat consumption) is partly responsible for the weight loss. In the carbohydrate management in European diets (CARMEN) study, however, a reduction in the fat content of the diet did not result in demonstrable differences in the consumption of dietary fibre (Sar00). Nevertheless, in this study, body weight in the intervention group fell by two kilograms, relative to the control group. The Committee concludes the effect on body weight of a reduction in fat consumption has little or nothing to do with an increase in the consumption of dietary fibre.

A reduction in the fat content of the diet is accompanied by an increase in the carbohydrate percentage, possibly in combination with an increase in the protein content of the diet. The changes in the percentage of total energy intake for carbohydrate and protein were not described in the above-mentioned meta-analyses. Nor indeed was there any attempt to determine the extent to which a change in protein consumption was responsible for the effect on body weight. The Committee assumes that the fats were replaced by both carbohydrate and protein, in a ratio that corresponds to the ratio in the usual diet (approximately 3:1) (Wes98). Accordingly, it is estimated that a reduction in the fat content of the diet equivalent to ten percent of total energy intake will be accompanied by an increase in the protein content by two to three percent of total energy intake. For the time being, the possibility cannot be excluded that an increase in protein consumption will lead to a reduction in body weight. If individuals are placed on a restricted energy diet, a substantial increase in protein consumption appears to result in greater weight loss. Under different conditions, however, no such effect could be demonstrated (see section 3.1.4, see also Skov *et al.* 1999 in figure 4.1: HP stands for high-protein and LP stands for low-protein). It is equally unclear whether a slight increase in protein intake can cause a drop in body weight.

Virtually all intervention studies investigated the effect of reducing the fat content of the diet (Ast00)**. It is unclear whether or not an increase in the fat content of the diet

* The energy density is the average amount of energy per gram of food consumed (including drinks).

** The study conducted by Weststrate *et al* is, in a certain sense, an exception to this rule. The intervention used in this study was also aimed at achieving a reduction in fat consumption (the reduction was equivalent to three percent of total energy intake) In contrast to the other studies, where fat consumption in the control group either remained virtually unchanged or showed a slight decrease, in Weststrate's study the control group's fat consumption increased by an average of five percent of total energy intake (Wes98).

would have the same effect on body weight. It may be that an increase in weight is more readily achieved than a weight loss. In addition, an increase in the fat content of the diet may cause a greater increase in weight than is suggested by the estimates from the available intervention studies. The answer to this question will have to come from future research.

In studies with a more protracted period of intervention, no further reduction in body weight was seen after a period of six months (Kat97, Wil98b). Only two of the studies reported had an intervention period of more than one year (Bla94, She91). In those studies, body weight remained low throughout the entire period of intervention. However, the difference between the intervention group and the control group decreased over time. The decline in the weight difference between the intervention group and the control group may have resulted from a reduction in dietary compliance.

The Dutch Food Consumption Surveys showed that from 1987 to 1997, fat consumption in adult males and females fell by approximately two percent of total energy intake (VCP98). In that period, there was an increase in the number of obese individuals in the country (VTV97). Since the development of overweight is influenced by a variety of factors, it cannot be assumed that there is a direct relationship between these findings. The Committee feels that this apparent discrepancy with regard to the findings of intervention studies is a result of other factors, most probably an increasingly widespread lack of exercise.

The Committee concludes that reducing the fat content of the diet by 10% of the total energy intake results in an average weight loss of two to three kilograms. This effect is mainly due to a reduced energy intake. The fat content of the diet has no effect on body weight if energy intake is equivalent to requirement. However, it has been shown that, on average, people on a diet with a low fat content tend to eat slightly less than those on a high-fat diet*. This effect is more pronounced in overweight individuals than in individuals who have an ideal body weight. The Committee emphasizes that the problem of obesity has a variety of causes. In this context, a reduction in the fat content of the diet may have only a limited part to play. This reduction will only have beneficial effects if the individual in question consumes less

* The Committee points out that reducing the fat content of the diet from 40% of total energy intake to 30% of total energy intake is equivalent to a 25% reduction in the fat content of the diet. When expressed in grams per day, fat consumption decreases by almost 30%.
Example of the calculation: A 40-year-old man with an energy requirement of 12.2 MJ/day has a diet with a fat content of 40% of total energy intake. This is equivalent to 128 grams of fat per day. If the fat content of his diet is reduced by 10% of total energy intake (to 30% of total energy intake), this is equivalent to a 25% reduction in fat content. If this man's weight falls by three kilograms in six months, his energy consumption will probably be approximately 0.5 MJ/day lower than his energy requirement, or 11.7 MJ/day. At a fat content of 30% of total energy intake, this man will consume 92 grams of fat per day. When expressed in grams per day, his fat consumption will have fallen by 128 minus 92 divided by 128, or 28%.

energy. For the time being, the possibility cannot be excluded that the effect on energy intake is partly due to the increased consumption of vegetables, fruit, carbohydrates, dietary fibre and proteins that usually accompanies a reduction in the fat content of the diet.

4.7.2 *Coronary heart disease*

No reliable intervention studies have been carried out on the effect of the fat content of the diet on the development of coronary heart disease (Cor97). The results of several earlier studies show no relationship between the fat content of the diet and the risk of coronary heart disease (MRC65).

The results of several prospective cohort studies indicate that the fat content of the diet has no effect on the development of coronary heart disease in men (Asc96, Pie97) or women (Liu00). In one study of this type, it was estimated that the iso-energetic replacement of carbohydrates by saturated fatty acids (both equivalent to five percent of total energy intake) increased the risk of coronary heart disease by 15%. However, when the carbohydrates were replaced by monounsaturated fatty acids or polyunsaturated fatty acids, this risk was reduced by 23% and 60% respectively (Hu97). In a prospective study of cardiac patients, however, it was found that diets with a higher fat content and increased levels of polyunsaturated fatty acids (a higher percentage of total energy intake) were actually risk factors for progressive atherosclerosis (Bla90).

The provision of food in intervention studies can either be carefully tailored or *ad libitum*. Studies in which the body weight of the test subjects is kept constant (tailored provision of food), deal with the direct effects of the fat content of the diet on the risk factors for coronary heart disease. There may also be indirect effects, since the fat content of the diet affects body weight (see section 4.7.1). Intervention studies using the *ad libitum* provision of food* describe the result of direct and indirect effects. Studies on the effect of body weight, where the fat content of the diet remains unchanged, describe the indirect effects. It is the Committee's view that the criterion used when formulating dietary reference intakes should be the result of direct and indirect effects.

When body weight remains unchanged, a low-fat diet produces adverse concentrations of HDL cholesterol and triglycerides in fasting blood. The effect on total cholesterol and LDL cholesterol depends on the fatty acid composition. In this connection, saturated fatty acids are less beneficial than carbohydrates, while unsaturated fatty acids are actually more beneficial (table 4.8). As a result of replacing

* In this type of study, it is the researchers who determine the composition of the diet, while the individual participants determine how much food they eat.

Table 4.8 Changes in serum cholesterol fractions associated with the iso-energetic replacement of carbohydrates by fats (both equivalent to 10% of total energy intake)^a.

	effect in comparison to carbohydrates, per ten percent of total energy intake		
	saturated fatty acids	monounsaturated fatty acids	polyunsaturated fatty acids
concentration of total cholesterol in the blood (mmol/l)	+ 0.39	(- 0.03)	- 0.15
concentration of LDL cholesterol in the blood (mmol/l)	+ 0.33	(- 0.06)	- 0.14
concentration of HDL cholesterol in the blood (mmol/l)	+ 0.12	+ 0.09	+ 0.07
ratio between total cholesterol and HDL cholesterol	(+ 0.03)	- 0.26	- 0.32
concentration of triglycerides in the blood (mmol/l)	- 0.25	- 0.22	- 0.28

^a Estimates from Men92, with the exception of the effects on the ratio between total cholesterol and HDL cholesterol. The latter estimates are from as yet unpublished meta-analysis results by Mensink *et al.* The values in brackets are not statistically significant.

unsaturated fatty acids with carbohydrates (both equivalent to 10% of total energy intake), it is estimated that the ratio between total cholesterol and HDL cholesterol increases from 0.26 to 0.32. The difference between monounsaturated fatty acids and polyunsaturated fatty acids is not statistically significant (Mensink *et al.*, results of an as yet unpublished meta-analysis). It is estimated that this change in the ratio of total cholesterol to HDL cholesterol will increase the risk of developing coronary heart disease during the subsequent ten years by half a percent to two percent*.

When food is provided *ad libitum* the fat content of the diet may have a different effect on the concentrations of lipids in the blood. This is because these concentrations are influenced not only by the changing fat content of the diet, but also by the changes in body weight. The meta-analysis by Yu-Poth *et al.* describes the effects of the 'Step I' diet of the National Cholesterol Education Program. This regime is intended to reduce the fat content of the diet, as well as reducing the saturated fatty acid and cholesterol contents (table 4.9, Yu99)**. Some of the studies that were used in the meta-analysis also focused on an increase in physical activity. It was stated in section 4.7.1 that, in

* The National Organization for Quality Assurance in Hospitals (CBO) produced a consensus document entitled 'Treatment and prevention of coronary heart disease by reduction of the plasma cholesterol concentration'. This showed that, in non-diabetic individuals, an increase in the ratio of total cholesterol to HDL cholesterol equivalent to the value of one led to a one to four percent increase in the risk of developing coronary heart disease in the coming ten years. This increase was dependent on the age group (40, 50, 60 or 70), on whether an individual was a smoker or a non-smoker, and on the presence or absence of hypertension (CBO98).

** The meta-analysis also deals with the effects of the 'Step II' diet. This dietary regime is not relevant to the contents of this section, as it is not intended to reduce the fat content of the diet (it's sole focus is to reduce the content of saturated fatty acids and cholesterol).

Table 4.9 Changes in serum cholesterol fractions associated with reductions in the amounts of total fat, saturated fatty acids and cholesterol in the diet, in studies where food was provided *ad libitum* (Yu99)^a.

	average effect ^b
concentration of total cholesterol in the blood (mmol/l)	- 0.63
concentration of LDL cholesterol in the blood (mmol/l)	- 0.49
concentration of HDL cholesterol in the blood (mmol/l)	(- 0.04)
ratio between the concentrations of total cholesterol and HDL cholesterol in the blood	- 0.50
concentration of triglycerides in the blood (mmol/l)	- 0.17

^a Meta-analyses of intervention studies into the effects of the 'Step I' diet of the National Cholesterol Education Program: fat content < 30 percent of total energy intake, saturated fatty acid content < 10 percent of total energy intake, cholesterol content < 300 mg. Some of the studies that were incorporated into this meta-analysis were aimed at reducing body weight and increasing physical activity.

^b The estimates shown in brackets are not statistically significant. The comparison of the average effects, using the data from figure 2 of the publication Yu99, shows that the estimates reflect the effect of a reduction in the fat content of the diet equivalent to 10% of total energy intake.

this meta-analysis, Yu-Poth *et al.* estimate that a reduction in the fat content of the diet equivalent to 10% of total energy intake will reduce body weight by 2.8 kilograms. The Committee points out that the reduction in cholesterol consumption and the increase in physical activity seen in some of the studies may be partly responsible for the effects on the concentrations of lipids in the blood.

The results in table 4.9 can best be compared with the data in the 'saturated fatty acids' column of table 4.8. It has been shown that the iso-energetic replacement of saturated fatty acids with carbohydrates has a favourable effect on the concentrations of total cholesterol and LDL cholesterol, but an unfavourable effect on HDL cholesterol and triglycerides. The most important predictive factor for coronary heart disease, the ratio between total cholesterol and HDL cholesterol, remains unchanged after the iso-energetic exchange of saturated fatty acids and carbohydrates. When food is made available on an *ad libitum* basis, the replacement of saturated fatty acids with carbohydrates has been shown to have no effect on HDL cholesterol. However, it did have a beneficial effect on total cholesterol, LDL cholesterol, the ratio between total cholesterol and HDL cholesterol, and the concentration of triglycerides in the blood. On the basis of a fall of 0.50 in the total cholesterol/HDL cholesterol ratio, the Committee estimates that when saturated fatty acids equivalent to 10% of total energy intake are replaced by carbohydrates, the risk of coronary heart disease falls by zero percent to two percent (based on CBO98, see footnote in the above part of this section).

The effect of replacing unsaturated fatty acids with carbohydrates, when food is provided *ad libitum* has not been studied. For this reason, the Committee compares the

values from table 4.8 (the direct effect) with the indirect effect of a reduction in fat consumption, namely the changes in the concentrations of lipids in the blood as a consequence of a reduction in body weight. The most authoritative study in this area was that of Leenen *et al.* (Lee93). They studied a group of overweight individuals, before and after they were placed on a restricted-energy diet. The blood samples were taken following periods (lasting at least three weeks) during which the test subjects were in energy balance. In 19 of the 41 test subjects the composition of the diet before and after weight loss remained the same. In this way, any effects on the concentrations of lipids in the blood would only be caused by the reduction in body weight. In the group in question, the ratio between total cholesterol and HDL cholesterol fell by 0.8 for each kilogram of weight lost. The results of two other (less well controlled) studies, are of the same order of magnitude (Pas97, Pas99). In section 4.7.1, it was estimated that there is a two to three kilogram reduction in body weight when the fat content of the diet is reduced by 10% of the total energy intake. Thus, on average, the indirect effect on the ratio of total cholesterol to HDL cholesterol would be -0.16 to -0.24 . The direct effect was previously estimated at $+0.26$ to $+0.32$ (table 4.8). This indicates that when polyunsaturated fatty acids are replaced by carbohydrates, the beneficial indirect effect that loss of body weight has on the total cholesterol/HDL cholesterol ratio is much smaller than the adverse direct effect of an iso-energetic exchange of fatty acids with carbohydrates. The Committee emphasizes that this summation of direct and indirect effects is a purely mathematical approach, one that requires confirmation from intervention studies into the effect of replacing unsaturated fatty acids with carbohydrates, when food is made available on an *ad libitum* basis. On the basis of the above, however, the Committee takes the view that the replacement of unsaturated fatty acids with carbohydrates is not beneficial.

The fat content of the diet probably has no effect on blood pressure (Men88, Mor94). The results of observational studies and intervention studies indicate that low-fat diets are associated with reduced factor VII activity in fasting and postprandial blood. This might result from the high dietary fibre content of low-fat diets (Mar98, Men98, Mil98).

Following the consumption of fats, plasma concentrations of lipids remain elevated for six to seven hours. The fat particles that circulate in the blood during this period (mainly chylomicrons) may have an atherogenic effect (Mie92, Pat92, Zil79). Patients with coronary heart disease have higher concentrations of lipids in postprandial blood than individuals who do not have this condition (Gro91, Pat92). The extent of this postprandial hyperlipidaemia is partly dependent on fat intake (Dub98, Shi99). To date there have been no prospective cohort studies into the effect of postprandial hyperlipidaemia on the risk of coronary heart disease. For this reason, it is not yet possible to draw any conclusions.

As was concluded in section 4.7.1, a reduction in the fat content of the diet equivalent to 10% of total energy intake results, on average, in a reduction of two to three kilograms in body weight. On the basis of the reference heights (see 1.6), this corresponds to an average reduction in the Quetelet Index* for adults of one kg/m². On the basis of two large American prospective studies (in which the cohorts were monitored for 10 years and 18 years) the Committee estimates that (for individuals with a Quetelet Index of less than 28%) a similar reduction in the Quetelet Index would reduce the risk of coronary heart disease by approximately ten percent. In the case of individuals with higher initial weights, there is probably an even more marked decline in the risk of coronary heart disease (Wil99).

The Committee concludes that, for individuals with a healthy and stable body weight, an increase in the fat content of the diet will have a beneficial effect on the concentrations of HDL cholesterol and triglycerides in fasting blood. In terms of these effects, the specific type of fat involved is relatively unimportant. The effects on the concentrations of total cholesterol and LDL cholesterol in fasting blood, however, are dependent on fatty acid composition. In this respect, saturated fatty acids are less beneficial than carbohydrates, while unsaturated fatty acids are more beneficial than carbohydrates. Provided that the fatty acid composition is beneficial, an increase in the fat content can therefore lead to favourable changes in the concentrations of lipids in fasting blood. However, a higher fat concentration is not beneficial for the concentration of triglycerides in postprandial blood and for the factor VII concentration in fasting and postprandial blood.

If the average effects on body weight are also taken into account, it seems likely that a reduction in the fat content of the diet (provided that the reduction only affects the intake of saturated fatty acids) will reduce the risk of coronary heart disease.

The Committee points out that a reduction in the fat content of the diet always leads to a reduction in the intake of both saturated fatty acids and unsaturated fatty acids, since all dietary fats contain a mixture of fatty acids. In this context it is important to remember that the 'visible fats' are often the most important source of fatty acids. These fats are those that are spread on bread, and those that used in cooking and at the table (butter, margarine's, oils, etc.). The 'invisible fats', which are fats that are naturally present in nutrients (such as meat and biscuits), consist of large amounts of saturated fatty acids. This should be taken into account when translating dietary reference intakes in terms of nutrients.

* The Quetelet Index is the body weight in kilograms divided by the square of the individual's height in metres.

4.7.3 Cancer

As with two recent studies of this type, a combined analysis of the results of seven prospective cohort studies was unable to link the fat content of the diet to the risk of breast cancer (Hol00, Hun96, Vel00). Fat intakes in the studies in question varied from less than 20% of total energy intake to more than 45% of total energy intake. A meta-analysis of the results of twelve controlled studies of patients showed that in postmenopausal women (but not in premenopausal women) a high-fat diet corresponded to an increased risk of breast cancer (How90). A meta-analysis of eight prospective studies in which the cohorts were monitored for three to seven years showed that individuals with a lower body weight had a lower risk of breast cancer (Bra00). However, in the case of an average reduction in the Quetelet Index of one kg/m² that can be achieved by reducing the fat content of the diet by 10% of total energy intake (see sections 4.7.1 and 4.7.2) the actual health gain is quite small. On the basis of the above meta-analysis, the Committee estimates that this produces a three percent reduction in the risk of breast cancer in postmenopausal women. One 2-year intervention study showed that a low-fat diet leads to a reduction in both the total amount of breast tissue and the amount of high-density breast tissue. These effects were primarily attributable to weight loss (Boy98). The fat content of the diet, independently of body weight, probably has no effect on the risk of developing breast cancer (COMA98).

In four of the five prospective cohort studies into the relationship between the fat content of the diet and the risk of developing colon cancer (in which a correction was made for energy intake), no such relationship was found (Bos94, Gio94, Gol94, Kam96). In the fifth cohort study, the Nurses' Health Study, a relationship was found between a high-fat diet and the risk of developing colon cancer (Wil90). Controlled studies of patients have failed to produce clear results. In a meta-analysis of thirteen studies of this type (in which a correction was made for energy intake) no correction was found between the fat content of the diet and the risk of developing colorectal cancer (How97). A 4-year intervention study found that a dietary pattern with a low intake of fat and a high intake of dietary fibre and vegetables had no influence on the risk of a recurrence of colorectal adenomas (Sch00).

In prospective studies, no link was found between the fat content of the diet and the risk of prostate cancer (Gio98, Sch99, Sev89, Vei97). The results obtained from controlled studies of patients are mutually inconsistent (WCRF97). Only a small number of animal experiments have been carried out to investigate a possible relationship, but the results are equally unclear.

One intervention study showed that halving the fat content in the diets of patients with skin cancer (other than melanoma) resulted in a 70% reduction in new lesions (Bla94).

The Committee endorses the conclusions of the COMA report, which stated that the fat content of the diet has little or no effect on the development of breast cancer (COMA98). The fat content of the diet probably has no effect on the development of colon and prostate cancer.

4.7.4 *Diabetes mellitus type 2*

To date, there have been no intervention studies into the influence of the fat content of the diet on the development of diabetes mellitus type 2. The results of some cohort studies and cross-sectional studies indicate that a reduction in the fat content of the diet is beneficial for glucose tolerance and insulin sensitivity (Fes99). This is supported by the results of intervention studies (Him35, Tho78). The effect in question is claimed to occur at carbohydrate intakes of up to 250 grams per day (Him35).

On average, reducing the fat content of the diet by 10% of the total energy intake produces a two to three kilogram reduction in body weight. This is equivalent to an average reduction of the Quetelet Index for adults of one kg/m² (see sections 4.7.1 and 4.7.2). The results of two large American prospective studies (in which the cohorts were monitored for 10 and 18 years) indicate that for individuals with a Quetelet Index of up to 28, this reduction in the Quetelet Index can reduce the risk of developing diabetes mellitus type 2 by approximately 30% (Wil99). In individuals with a higher Quetelet Index, weight loss will probably result in an even more marked reduction in the risk of developing diabetes mellitus type 2.

The study results appear to show that a low dietary fat level is beneficial for glucose tolerance and insulin sensitivity. Body weight may play a major part in this. If the average effects on body weight are taken into consideration, the Committee thinks it likely that a reduction in the fat content of the diet will reduce the risk of developing diabetes mellitus type 2.

4.7.5 *Adequate intake*

The adequate intakes for total fat are set out in table 4.10. Explanations for several age-groups are given below.

Age groups from birth to four years of age

The Committee has set the adequate intake for infants from birth to five months at the average fat content of human milk (40-45% of total energy intake).

For infants aged from six to eleven months, the Committee endorses the recommendation of the European Society of Paediatric Gastroenterology, which sets the adequate intake at 40% of total energy intake (Eur91).

There are no indications that the current average fat intake of Dutch children aged from 1 to 3 (approximately 30% of total energy intake) leads to growth problems (VCP98). Retarded growth and development have been observed, however, in the case of children on a macrobiotic diet, with a fat intake of approximately 20% of total energy intake (Dag89). On the basis of this data, the Committee feels that children in this age group require an amount of fat equivalent to at least 25% of total energy intake.

Individuals aged four and above, with an optimal body weight

The dietary reference intakes are intended for healthy children and adolescents with an average body weight and rate of growth, and for healthy adults of average height and with a Quetelet Index of 22.5 (see section 1.6.2). The dietary reference intakes have therefore been drawn up for individuals with an ideal body weight. Given this condition, the effect of the fat content of the diet on body weight has not been taken into consideration.

There is no convincing evidence that the fat content of the diet has an effect on the development of coronary heart disease, cancer and diabetes mellitus type 2. The Committee feels that a diet with a fat content of less than 20% of total energy intake has an adverse effect on the concentration of HDL cholesterol and triglycerides in the blood. In the Netherlands, linoleic acid provides at least 10% of the fat in the diet (based on Hul98). An amount of fat equivalent to 20% of total energy intake is therefore sufficient for an adequate intake of linoleic acid (two percent of total energy intake). A given level of fat intake is also required for the intestinal absorption of lipid-soluble vitamins. A daily intake of 5 to 10 grams of dietary fat is probably sufficient for this purpose (Jeq99)*.

A fat content in excess of 40% of total energy intake is undesirable due to possible adverse effects on the postprandial concentration of lipids in the blood and on the concentration of blood coagulation factor VII. This upper limit is partly based on current average fat consumption in the Netherlands, which is a little less than 40% of total energy intake.

* Since dietary reference intakes are based on the physiological requirement for nutrients, the Committee has not taken into account the average fat consumption associated with an ideal intake of lipid-soluble vitamins.

The Committee concludes that the fat content of the diet in healthy individuals with an ideal weight should be between 20% and 40% of total energy intake. The composition of this dietary fat should conform with the dietary reference intakes set out in sections 4.1 to 4.6.

Individuals aged four and above, who are overweight or who experience undesirable weight gains

As already mentioned, in the above section the Committee has taken no account of the effect of a diet's fat content on body weight. In section 4.6.1, however, it was concluded that reducing the fat content of the diet results in weight loss. There is an increasing incidence of overweight individuals in the Netherlands (VTV97). The increasingly widespread lack of exercise in the Dutch population probably plays an important part in this. Reducing fat consumption to no more than 30% to 35% of total energy intake can help to prevent and combat overweight. This is important for the prevention of diabetes mellitus type 2 and coronary heart disease.

Table 4.10 Adequate intake for total fat.

group	subgroup	adequate intake as percentage of total energy intake
0 to 5 months	-	50
6 to 11 months	-	40
1 to 3 years of age	-	25-40
≥ 4 years of age	individuals with an ideal body weight ^a	20-40
	overweight individuals or those with undesirable weight gains	20-30/35

^a This is the group for whom the dietary reference intakes were drawn up.

4.8 Comparison with other reports on dietary reference intakes

Annex B shows the adequate total fat intake for several age groups (table B4), the adequate intake for fatty acids (table B5) and the tolerable upper intake level for saturated fatty acids, *trans* fatty acids and monounsaturated fatty acids (table B6) in the present recommendation and the values given in various other reports.

The upper limit of the adequate intake zone for total fat in individuals who are overweight or who experience undesirable weight gains (30% or 35% of total energy intake in the present recommendation) shows good agreement with previous Dutch

values and with the values used in the Scandinavian countries, the German-speaking countries, Great Britain and the United States. However, there are two points on which the present recommendation differs from the previous reports in annex B. Firstly, in the case of individuals with an ideal body weight, it has been indicated that there is no objection to a slightly higher fat consumption (40% of total energy intake). Secondly, the present recommendation has a lower limit for fat intake (20% of total energy intake).

Annex B5 shows that the fatty acid groups for which dietary reference intakes have been drawn up can vary from one recommendation to another. Dietary reference intakes are generally fixed for n-6 fatty acids or linoleic acid, and for n-3 fatty acids or alpha-linolenic acid. In the present recommendation, the dietary reference intakes for linoleic acid largely correspond to those for linoleic acid or n-6 fatty acids in previous Dietary Reference Intakes in the Netherlands, and in the European Commission's recommendation. In the case of alpha-linolenic acid, however, the value set in the present recommendation exceeds the values given in other recommendations. The present recommendation contains dietary reference intakes for n-3 fatty acids from fish, and a value (which was derived from other dietary reference intakes) for the total intake of unsaturated fatty acids. No values for these fatty acid groups were derived in the other recommendations.

The tolerable upper intake level for saturated fatty acids and *trans* fatty acids in the present recommendation corresponds to the values used in other countries. In the case of polyunsaturated fatty acids, the present recommendation gives a slightly higher upper limit (12% of total energy intake) than the recommendations for the Scandinavian countries, Great Britain and the United States (10% of total energy intake). However, the value quoted in the European Commission's recommendation is higher (15% of total energy intake) than that given in this recommendation.

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Digestible carbohydrates

Summary *137*

5.1 Introduction *137*

5.1.1 Nomenclature, properties and occurrence *137*

5.1.2 Physiological significance *138*

5.1.3 Deficiency symptoms *139*

5.1.4 Chronic diseases *139*

5.2 Factors that affect requirement *143*

5.2.1 Dietary factors *143*

5.2.2 Other factors *143*

5.3 Recommended dietary allowance *143*

5.3.1 Derivation method *143*

5.3.2 Values *144*

5.4 Comparison with other reports on dietary reference intakes *146*

References *146*

Summary

In the case of carbohydrates, a recommended dietary allowance has been derived for each age group. For infants from birth up to an age of five months this is based on the average intake of baby's receiving no other food than human milk. For all other groups it is based in the 97.5 percentile of endogenous glucose production. For details of the values, see table 5.1 in section 5.3.2. No tolerable upper intake level has been derived for carbohydrates.

5.1 Introduction

5.1.1 *Nomenclature, properties and occurrence*

This chapter deals with those carbohydrates than can be digested by humans. These are referred to in the remainder of this chapter as 'carbohydrates'. These include the monosaccharides glucose, fructose and galactose, the disaccharides sucrose (glucose and fructose), lactose (glucose and galactose) and maltose (two glucose molecules), some oligosaccharides and polysaccharides, such as starch. Monosaccharides and disaccharides are referred to as simple carbohydrates, whereas polysaccharides are referred to as complex carbohydrates.

Many nutrients contain a mixture of simple and complex carbohydrates. Fruit primarily contains fructose, while dairy products mainly contain lactose. Beet sugar and cane sugar contain sucrose, the most common disaccharide in human diets. Major sources of starch are potatoes, grains and legumes. Meat and meat products provide small quantities of polysaccharides, in the form of glycogen.

Glycaemic index

The consumption of carbohydrates causes the glucose concentration in the blood to rise. This glycaemic response is dependent not only on the amount of carbohydrates consumed, but also on the type of carbohydrates involved, and on other properties of the food that is supplying the carbohydrates. The glycaemic response caused by a food is measured in terms of the glycaemic index, the glycaemic load and the average glycaemic index.

Foods with a lower glycaemic index cause a slower, more gradual increase of the glucose concentration in the blood than do nutrients with a higher glycaemic index. The glycaemic index is defined as the increase in the glucose concentration of the blood over a period of two hours after the consumption of foods containing 50 g of

carbohydrates. It is expressed as a percentage of the response after consumption of 50 g of glucose or an amount of white bread that contains 50 g of carbohydrates (Rob00). The glycaemic load of foodstuffs is estimated by multiplying the intake of each carbohydrate-containing nutrient by its glycaemic index, then adding up the results obtained. The average glycaemic index is the glycaemic load divided by the total intake of carbohydrates (Liu00).

The body obtains relatively little glucose from sucrose and lactose. These substances therefore generate a lower glycaemic index than glucose or starch. The glycaemic index can be influenced by ingredients other than carbohydrates. For example, by forming a gel in the stomach, water-soluble fibres can delay the emptying of the gastric contents into the small intestine. As a result, the carbohydrates in food enter the blood at a slower rate, producing a lower glycaemic index than would have been the case if the same quantity of carbohydrates had been consumed without water-soluble fibres (Rob00). However, the ratio between simple and complex carbohydrates has little influence on the glycaemic index (Liu00).

5.1.2 *Physiological significance*

Digestive enzymes, such as amylase, break down carbohydrates into monosaccharides, after which active absorption can take place. The body can either use fructose as fuel or convert it to glucose. Galactose is converted to glucose. Glucose has a major role as a supplier of energy, since every type of cell in the body is able to metabolize glucose. Most of the body's cells can also use fatty acids and amino acids as a source of energy. However, glucose is the major source of energy for brain cells, red blood cells, kidney medulla cells, foetal tissue and mammary glands. Brain cells can also use keto-bodies as a source of energy (For94, Mar94).

The concentration of glucose in the blood remains within narrow limits, even when the diet contains little or no carbohydrate for protracted periods of time. A slight reduction in glucose concentration causes a drop in insulin production. One result of this is gluconeogenesis, which is when the liver and kidneys create glucose from lactic acid and amino acids. In low-carbohydrate diets, fats become a more important source of energy. As a result, more free fatty acids enter the blood. It is these free fatty acids that stimulate gluconeogenesis (Bod97). The amino acids needed for gluconeogenesis are supplied by the breakdown of body protein. The diet must therefore contain a certain amount of carbohydrates, in order to counteract the breakdown of body protein.

The body can store glucose as glycogen (in the liver and muscles) or as fat. There is a limit to the amount of glycogen that can be stored, but no limit to the amount of fat. Compared to fat, glycogen is a rapidly available source of energy. Per unit of oxygen, the body can release more energy from glucose than it can from fat. It can also release

a limited amount of energy from glucose in the absence of oxygen, but this is not possible with fat (Pas86, Sau98).

5.1.3 *Deficiency symptoms*

As mentioned in section 5.1.2, an excessively low intake of carbohydrates can lead to the breakdown of body protein. Long-term adherence to a low-carbohydrate diet results in reduced gluconeogenesis. However, this does not lead to a reduction in the concentration of glucose in the blood, since peripheral tissues simultaneously become less sensitive to insulin. As a result, there is reduction in the amount of glucose that they take up from the blood and oxidize. Thus, under these conditions, the development of a certain level of insulin resistance helps to ensure that the glucose content of the blood remains virtually constant (Bis00, Bis01).

5.1.4 *Chronic diseases*

The following section is partly based on the Committee's conclusions in section 4.6, concerning the effects of the fat content of the diet on chronic diseases. In addition, the effects of various types of carbohydrates are described.

Overweight

While energy intake is equal to energy requirement, the replacement of one macronutrient by another has no effect on body weight. On the basis of intervention studies in which food was provided *ad libitum*, however, the Committee concludes that reducing the fat content of the diet by 10% of total energy intake will produce an average weight loss of two to three kilograms (see section 4.7.1). This effect is primarily caused by a reduced intake of energy. It has been shown that, on average, people on a diet with a low fat content tend to eat slightly less than those on a high-fat diet. A reduction in the fat content of the diet not only results in an increase in the carbohydrate content of the diet, it also produces other changes in eating habits such as an increase in the consumption of proteins, vegetables and fruit.

In comparison to meals with a low glycaemic index (see section 5.1.1), meals with a high glycaemic index lead to a 30% greater intake of energy in subsequent hours (Rob00). As a result of the short duration of the available studies (no more than one day), the Committee does not consider it appropriate to draw any conclusions concerning the effect of the glycaemic index on energy intake. The effects on body weight have not been investigated.

A recent intervention study compared the effect on body weight of a diet that was rich in simple carbohydrates and a diet that was rich in complex carbohydrates. The diets had virtually the same carbohydrate content and were available *ad libitum*. The intervention lasted for six months. The test subjects were all overweight individuals. The average weight loss was 0.9 kg in the group that consumed large amounts of simple carbohydrates and 1.8 kg in the group that consumed large amounts of complex carbohydrates. However, the difference was not statistically significant (Sar00).

In one 5-day experiment involving 13 women, an amount of sucrose, glucose or fructose equivalent to 50% of the total energy intake was added to a diet that met the energy requirement. In the resultant overconsumption, the three types of carbohydrate appeared to have similar effects on 24-hour energy consumption and on the storage of glycogen and fat (McD00).

The Committee concludes that the carbohydrate content of the diet has no influence on body weight as long as energy intake is equal to requirement. On the basis of the available evidence, this is not dependent on the exact type of carbohydrate used.

Coronary heart disease

When fats are replaced by carbohydrates, the higher the carbohydrate content of the diet the more adverse are the concentrations of HDL cholesterol and triglycerides in fasting blood. The effect on the concentrations of total cholesterol and LDL cholesterol in fasting blood are dependent of the type of fatty acid that has been replaced by carbohydrates. In this regard, carbohydrates are more beneficial than saturated fatty acids, but less beneficial than unsaturated fatty acids. Thus, in comparison to fats with an ideal fatty acid composition, carbohydrates have an adverse effect on the concentrations of lipids in fasting blood. However, a carbohydrate diet seems to be beneficial for the concentration of triglycerides in postprandial blood and for the factor VII concentration in fasting and postprandial blood (see section 4.6.2).

There is some evidence that, relative to complex carbohydrates, simple carbohydrates cause the concentration of triglycerides in the blood to increase (Par00). However, this was not confirmed by the results of a 6-month-long intervention study (Sar00). In a prospective cohort study that monitored more than 75,000 38 to 63-year-old women for ten years, neither the intake of simple carbohydrates nor that of complex carbohydrates was found to be related to the development of coronary heart disease (Liu00).

In the above cohort study, diets with both a high glycaemic load and a high average glycaemic index (see section 5.1.1) were risk factors for the development of coronary heart disease (Liu00). However, this was not confirmed by the results of another

prospective cohort study in 64 to 85-year-old men, which also had a 10-year follow-up period (Dam00). It may be that the glycaemic index of a diet affects the risk of coronary heart disease in women but not in men (Fro99).

The intake of specific carbohydrates was unconnected to the development of coronary heart disease (Liu00).

The Committee concludes that carbohydrates, in comparison to fats with an optimum fatty acid composition, have an adverse effect on the concentration of lipids in fasting blood, but favourable effects on the concentration of triglycerides in postprandial blood and on factor VII concentrations in fasting and postprandial blood. It is not yet clear what influence glycaemic load has on the development of coronary heart disease.

Cancer

Most epidemiological studies into the effect of carbohydrate consumption on cancer risk have focused on dietary fibre, and to a far lesser extent on monosaccharides and disaccharides or starch. Two recent intervention studies, which used the occurrence of colonic adenomas as the yardstick for results, found little evidence to support the view that fibre has a protective effect on the development of colorectal cancer (Alb00, Sch00).

Some results of observational epidemiological studies indicate that unrefined starch reduces the risk of cancer of the large intestine, that refined starch increases the risk of gastric cancer and that sucrose increases the risk of cancer of the large intestine (WCRF97). As yet there is no evidence to support any of these possible links.

The Committee feels that the consumption of carbohydrates is unlikely to influence the risk of cancer.

Diabetes mellitus type 2

In a prospective cohort study in which 64 to 87-year-old individuals were followed up for four years, those who developed glucose intolerance had a slightly higher carbohydrate intake than the remaining individuals (Fes91). No such connection was found either in a similar 20-year study of elderly men (Fes95) or in a 6-year study of 55 to 70-year-old women (Mey00). However, the results of various cohort studies and controlled studies of patients seem to indicate that glucose tolerance and insulin sensitivity benefit from a carbohydrate-rich diet (Fes99). This is supported by the results of an intervention study (Sar00). The effect in question is claimed to occur at levels of carbohydrate intake of up to 250 grams per day (Him35, Mac99).

According to the results obtained from various prospective cohort studies, simple and complex carbohydrates have no effect on the development of glucose intolerance (Fes91, Fes95, Ha98). One study of this type investigated the effects of individual carbohydrates. The results indicate that the risk of diabetes is increased by glucose and fructose but decreased by sucrose. No relationship was found in the case of starch, lactose and maltose (Mey00). Neither the glycaemic load nor the average glycaemic index of a diet appear to influence the development of diabetes (Sal97a, Sal97b).

The type of food from which the carbohydrates are derived may (in part) determine their effect on glucose tolerance. Cakes and confectioneries are thought to be harmful, while legumes and potatoes are considered to be beneficial (Fese91, Fes95). This may mean that the effect is caused by other ingredients of these foods, and not by the carbohydrates.

Although a high carbohydrate intake may be beneficial in terms of glucose tolerance and insulin sensitivity, the Committee is not convinced that a carbohydrate-rich diet decreases the risk of diabetes mellitus type 2. Equally unproven, in their view, is the assertion that the intake of specific types of carbohydrates has an effect on glucose tolerance and on the development of diabetes mellitus type 2.

Dental caries

The intake of carbohydrates always involves potential harm to the teeth. Whether or not this actually results in dental caries depends on the individual in question. It depends on the frequency of carbohydrate intake and on the individual's dental hygiene practices. Where there is an adequate supply of fluoride and the intake frequency is not excessive, then the risk of developing caries is quite small. It is important to pay specific attention to the prevention of baby-bottle caries, which is caused by the frequent use of a baby bottle when giving carbohydrate-containing drinks to young children.

The Committee takes the view that the stated effects of carbohydrates on the development of dental caries do not require any modification of the derived dietary reference intakes for carbohydrates that are set out in section 5.3.

5.2 Factors that affect requirement

5.2.1 *Dietary factors*

Bioavailability

The small intestine fully absorbs monosaccharides and disaccharides, most oligosaccharides and refined starch. Resistant starch is a form of starch that cannot be fully absorbed by the small intestine (Von00).

5.2.2 *Other factors*

Body weight

The endogenous glucose requirement is partly dependent on body weight. The Committee took this into consideration when setting the recommended dietary allowances (see section 5.3.1).

Physical activity

In the case of intensive physical activity, performance is improved when the diet contains high levels of carbohydrates. In addition, a carbohydrate-rich diet with a high average glycaemic index promotes the recovery of muscle tissue and the restoration of glycogen stocks following such activity. At low levels of effort, the carbohydrate content of the diet is of little importance in terms of performance and recovery (Mil99, SCF00).

5.3 Recommended dietary allowance

5.3.1 *Derivation method*

As was pointed out in section 5.1.2, it is important that the diet contain a certain amount of carbohydrate, in order to counteract the breakdown of body protein. Protein breakdown reaches a peak when the diet contains no carbohydrates and glycogen stocks are exhausted. The Committee bases the recommended dietary allowance of carbohydrate on the 97.5 percentile for the endogenous production of glucose. Studies involving the use of stable isotopes have shown that, at this level of carbohydrate intake, the breakdown of tissue protein is minimal (Dek96, Gam46, Kal99, Sau98).

The daily endogenous glucose production of new-born babies, children, adolescents and adults is estimated to be 7.2, 5.8, 4.3 and 2.9 grams per kilogram respectively (Kal99). The Committee assumes that these groups are representative of the 0, 7, 15 and 18 age groups. Linear interpolation is then used to derive the values for the 'median age' in each age group. Multiplying by the reference weight (see section 1.6) produces the average endogenous glucose production in grams per day. The Committee assumes that the coefficient of variation for endogenous glucose production (in grams per day) is 20% (see section 1.2.2). Thus the 97.5 percentile for endogenous glucose production is 1.4 times the average endogenous glucose production. This value is converted to the amount of carbohydrate as a percentage of total energy intake by multiplying it by the energy content of carbohydrates (17 kJ per gram) and then dividing by the estimated average requirement for energy.

5.3.2 Values

The recommended dietary allowance is based on the 97.5 percentile of endogenous glucose production, expressed as a percentage of the total energy intake (see section 5.3.1). In this connection, no distinction is made on the basis of gender. Table 5.1 shows the results and the recommended dietary allowance. Brief explanations for some groups are provided below.

Infants

The Committee assumes that human milk is the ideal diet for infants of up to six months of age (see section 1.4.5). Baby's receiving no other food than human milk consume on average 60 gram of carbohydrates per day or 10 grams per kilogram of body weight per day (Fom93)*. This is the adequate intake for babies from birth to five months of age. During this period, average endogenous glucose production amounts to 40-45 g/day (Bie77, Kal99). Thus, the 97.5 percentile of this endogenous glucose production (55-60 g/d) is virtually identical to the intake of carbohydrates via human milk.

The saliva of the new-born contains virtually no amylase. For this reason, starch is an inappropriate nutrient for infants aged up to 3 or 4 months.

Adults, pregnancy and lactation

No data is available for endogenous glucose production in the elderly. The Committee assumes that the recommended dietary allowance for carbohydrate, expressed as a

* Approximately 95% of the carbohydrate in human milk consists of lactose, 3 to 4% is glucose and the rest consists of oligosaccharides.

Table 5.1 Derivation of the recommended dietary allowance for carbohydrates.

age group	reference weight ^a	endogenous glucose production				recommended dietary allowance
		average		97.5 percentile ^b		
	<i>kg</i>	<i>g/[kg.d]^c</i>	<i>g/d^d</i>	<i>g/d</i>	<i>energy%^e</i>	<i>energy%^f</i>
0 to 5 months	5.75	7.2	41	58	47	10 g/[kg.d] ^g
6 to 11 months	8.75	7.1	62	86	49	50
1 to 3 years of age	13.75	6.7	92	129	46	45
4 to 8 years of age	23.75	5.9	140	196	46	45
9 to 13 years of age	40.5	5	201	281	46	45
14 to 18 years of age	62	3.6	223	312	42	40
19 to 30 years of age	69.5	2.9	202	282	42	40
31 to 50 years of age	67	2.9	194	272	42	40
51 to 70 years of age	-	-	-	-	-	40
> 70 years of age	-	-	-	-	-	40
pregnancy	-	-	-	-	-	40
lactation	-	-	-	-	-	40

^a Average of the reference weights for men and women (see section 1.6).

^b Calculated as the average endogenous glucose production plus twice its standard deviation. The Committee assumes that the coefficient of variation for endogenous glucose production has a value of 20%. It therefore calculates the 97.5 percentile as 1.4 x the average value.

^c The values are based on data from Kal99 (see description in the text).

^d Calculated by multiplying the endogenous glucose production in g/kg per day by the reference weight.

^e Energy% stands for the percentage of total energy intake.

^f The recommended dietary allowances are expressed as a percentage of total energy intake. An adequate intake has been determined for babies from birth up to an age of five months. This is expressed in grams per kilogram per day.

^g The adequate intake for babies from birth to five months is based on the average carbohydrate intake of baby's receiving no other food than human milk. The value is virtually the same as the 97.5 percentile of endogenous glucose production (see the text of section 5.3.2).

percentage of total energy intake does not increase with advancing age. During pregnancy, endogenous glucose production (in grams per kilogram per day) remains unchanged (Ass93, Kal97). This means that the recommended dietary allowance for pregnant women is the same as for non-pregnant women.

5.4 Comparison with other reports on dietary reference intakes

Table B7 in annex B, compares the amounts of carbohydrates that have been recommended in this report with the adequate intakes for several age groups taken from other reports. It can be seen from this table that the Committee has set relatively low values. This is the result of the derivation method. In the present recommendation, the Committee used estimates of average requirement and the variation in requirement. The recommended dietary allowance calculated in this way is a lower limit for the intake*. In the other recommendations, carbohydrates are generally used as a way of balancing energy intake. An adequate intake was derived on the basis of this criterion.

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* In this connection, the Committee points out that for many individuals a lower intake will not result in deficiency, see section 1.7.

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The Hague, 18 July 2001,
for the Committee

(signed)

dr ir CJK Spaaij,
Scientific Secretary

prof. dr HKA Visser,
Chairman

A	Committee and working group	153
B	Dietary reference intakes in other reports	157
C	Intake of energy and of the nutrients dealt with in this recommendation	163

Annexes

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Dietary reference intakes in other reports

In this annex, dietary reference intakes in the present recommendation are compared with the equivalent dietary reference intake in previous recommendations:

- *Netherlands 1992*
Food and Nutrition Council. Dietary Reference Intakes in the Netherlands, 1989 (2nd edition). The Hague: Netherlands Bureau for Food and Nutrition Education, 1992.
 - *Germany, Austria, Switzerland 2000*
Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährung, Schweizerische Vereinigung für Ernährung. Referenzwerte für die Nährstoffzufuhr. (1st edition). Frankfurt am Main: Umschau/Braus, 2000.
 - *Scandinavia 1996*
Nordiska Ministerrådet. Nordiska näringsrekommendationer 1996. Köpenhamn: Nordiska Ministerrådet, 1996.
 - *European Commission 1992*
European Commission. Nutritional and energy intakes for the European community. Reports by the Scientific Committee for Food (31st series). Luxembourg; EC, 1992.
 - *Great Britain 1991*
Department of Health. Dietary reference values for food energy and nutrients for the United Kingdom. Report of the panel on dietary reference values of the committee on medical aspects of food policy. London: HMSO, 1991.
-

Table B1 Reference weight in kilograms.^a

	age									
	1 month	5 years of age		15 years of age		40 years of age		80 years of age		
		M	F	M	F	M	F	M	F	
the present recommendation	4.5 or 5.8 ^b	24	23.5	65	59	72	62	74	63	
the Netherlands 1992	5.5	22.5	20.5	54	54	75	65	70	65	
Scandinavia 1996	5.3	19	19	62	55	70	60	70	60	
Germany, Switzerland, Austria 2000	4.9	20	19	67	58	74	59	68	55	
Great Britain 1991	-	19	19	63	55	74	60	69	60	
European Commission 1992	4.9	20	19	-	-	75	62	74	66	
United States 1989	6	20	20	66	55	79	63	77	65	

^a M = boys and men; F = girls and women

^b The reference weight of 4.5 kg is applicable to the birth to two-month age group (used in the chapters on energy and proteins); the reference weight of 5.8 kg is applicable to the birth to five-month age group (used in the chapters on fats and carbohydrates).

Table B2 Average energy requirement in MJ/d.^a

	age										pregnancy	lactation
	1 month	5 years		15 years		40 years		80 years				
		M	F	M	F	M	F	M	F			
the present recommendation	1.8	7.2	6.5	14.0	10.4	12.2	9.7	9.3	7.8	+ 1.2	+ 2.1	
the Netherlands 1992	2.2	7.3	6.7	11.1	10.0	11.2	8.7	8.8	7.8	+ 0.6	+ 2.5	
Scandinavia 1996	2.1-2.6	7.1	6.8	11.3	9.0	11.4	9.1	9.4	8.2	+ ≤1.1	+ ≤2.0	
Germany, Switzerland, Austria 2000	2.0	6.4	5.8	13.0	10.8	12.0	9.5	9.5	7.5	+ 1.1	+ 2.7	
Great Britain 1991	2.3	7.2	6.5	11.5	8.8	10.6	8.1	8.8	7.6	+ 0.3	+ 2.2	
European Commission 1992	2.2	6.9	6.4	11.4	8.9	11.3	8.5	8.0	7.3	+ 1.4	+ 1.7	
United States 1989	2.7	7.5	7.5	12.6	9.2	12.1	9.2	9.6	8.0	+ 0.8	+ 2.1	

^a M = boys and men; F = girls and women

Table B3 Recommended dietary allowance of protein, in grams per day.^a

	age										pregnancy	lactation
	1 month	5 years		15 years		40 years		80 years				
		M	F	M	F	M	F	M	F			
the present recommendation	8.5	22	21	56	49	59	50	60	51	+ 10	+ 13	
the Netherlands 1992	13	47	43	70	65	71	55	56	52	+ 15	+ 16	
Scandinavia 1996	10.5	53	51	85	68	86	68	71	62	+ 8	+ 15	
Germany, Switzerland, Austria 2000	10	18	17	60	46	59	47	54	44	+ 11	+ 16	
Great Britain 1991	12.5	20	20	55	45	56	45	53	47	+ 6	+ 11	
European Commission 1992	-	19	19	54	46	56	47	56	47	+ 10	+ 16	
United States 1989	13	24	24	59	44	63	50	63	50	+ 10	+ 15	

^a M = boys and men; F = girls and women

Table B4 Adequate intakes for fats, as a percentage of total energy intake.

	age					pregnancy	lactation
	1 month	5 years	15 years	40 years	80 years		
the present recommendation	50	at energy balance and ideal body weight or ideal weight gain: 20-40; in cases of overweight and undesirable weight gains: 20-30/35					
the Netherlands 1992	50	30-35	30-35	30-35	30-35	30-35	30-35
Scandinavia 1996	40-55	≤30	≤30	≤30	≤30	≤30	≤30
Germany, Switzerland, Austria 2000	45-50	30-35	normally ≤30; at high activity levels ≤35			35	35
Great Britain 1991	-	35	35	35	35	35	35
European Commission 1992	-	-	-	-	-	-	-
United States 1989	-	≤30	≤30	≤30	≤30	≤30	≤30

Table B5 Adequate intakes of fatty acids (energy percent, unless another unit is indicated).^a

	age				pregnancy				lactation										
	1 month				5, 15, 40, and 80 years														
	n-6 fatty acids	n-3 fatty acids	n-6 fatty acids	n-3 fatty acids	n-6 fatty acids	n-3 fatty acids	n-6 fatty acids	n-3 fatty acids	n-6 fatty acids	n-3 fatty acids	n-6 fatty acids	n-3 fatty acids							
LA	aLNA	total	LA	total	aLNA	n-3 fatty acids in fish	total	MUFA +PUFA	LA	total	aLNA	total	LA	total	aLNA	total			
this report	0.6 g/ [kg.d]	-	0.08 g/ [kg.d]	-	2.0	-	1.0	0.2 g/d	-	8-38 or 8-28/33 ^b	2.5	-	1.0	-	2.5	-	1.0	-	
Netherlands 1992	3.0	-	-	-	2.0	-	-	-	-	-	2.5	-	-	-	3.0	-	-	-	
Scandinavia 1996	-	-	-	-	-	-	3.0	-	0.5	-	essential fatty acids: 5	-	-	-	essential fatty acids: 5	-	-	-	
Germany, Switzerland, Austria 2000	-	4.0	-	0.5	-	2.5	-	-	0.5	-	-	2.5	-	-	0.5	-	2.5	-	0.5
Great-Brittain 1991	1.0	-	0.2	-	1.0	-	0.2	-	-	-	1.0	-	0.2	-	1.0	-	0.2	-	
European Committee 1992	-	-	-	-	-	-	2.0	-	0.5	-	-	2.0	-	-	0.5	-	2.0	-	0.5
United States 1989	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

^a All adequate intakes represent the fatty acids in the *cis*-configuration.

LA = linolic acid (C18:2 n-6);

αLNA = alfa linoleic acid (C18:3 n-3);

MUFA = monounsaturated fatty acids;

PUFA = polyunsaturated fatty acids.

^b The adequate intake of *cis* unsaturated fatty acids is not based on study results concerning this group of fatty acids, but calculated as the value for total fat minus those for saturated and for *trans* fatty acids. The upper limit of 38 energy percent applies to persons four years of age or older with a desirable bodyweight, and the upper limit of 28/33 energy percent to people four years of age or older with overweight or unwanted weight gain.

^c The adequate intake of n-3 fatty acids - as contained in fish - is unchanged during pregnancy and lactation.

Table B6 Tolerable upper intake levels for fatty acid groups, as a percentage of total energy intake.

	age 5, 15, 40 and 80, pregnancy and lactation		
	saturated fatty acids	<i>trans</i> fatty acids	polyunsaturated fatty acids
the present recommendation	10	1	12
the Netherlands 1992	10	-	-
Scandinavia 1996	saturated fatty acids plus <i>trans</i> fatty acids: 10		10
Germany, Switzerland, Austria 2000	10	1	10
Great Britain 1991	10	2	10
European Commission 1992	-	-	n-3 + n-6 fatty acids: 15 n-3 fatty acids: 5
United States 1989	10	-	10

Table B7 Recommended dietary allowances and adequate intakes for digestible carbohydrates, as a percentage of total energy intake.

	age					pregnancy	lactation
	1 month	5 years	15 years	40 years	80 years		
the present recommendation	10 g/[kg.d]	45	40	40	40	40	40
the Netherlands 1992	40	55	55	55	55	55	55
Scandinavia 1996	35-55	55-60	55-60	55-60	55-60	55-60	55-60
Germany, Switzerland, Austria 2000	45	>50	>50	>50	>50	>50	>50
Great Britain 1991	-	50	50	50	50	50	50
European Commission 1992	-	-	-	-	-	-	-
United States 1989	-	≥50	≥50	≥50	≥50	≥50	≥50

Intake of energy and of the nutrients dealt with in this recommendation

Tables C1 to C4 show the average intake and its standard deviation, for energy, proteins, carbohydrates, fats, linoleic acid, saturated fatty acids, monounsaturated fatty acids and polyunsaturated fatty acids, in the 1997-1998 Dutch Food Consumption Survey (source: Hulshof KFAM, Kistemaker C, Bouman M. The intake of energy and nutrients by Dutch population groups - 1997-1998 Food Consumption Survey. TNO report V98.805. TNO Nutrition and Food Research Institute, Zeist, 1998).

Tables C5 to C7 show the average fatty acid concentrations in the diets of middle-aged men who participated in the Seven Country Study. The data reflect 1960 diets, but the nutrients were collected and analyzed in 1987 (source: de Vries JHM, Jansen A, Kromhout D, *et al* 'The fatty acid and sterol content of food composites of middle-aged men in seven countries'. *J Food Composition and Analysis* 1997; 10: 115-141).

Tables C8 and C9 provide information about the distribution of the intake of alpha-linolenic acid in various populations.

Table C1 Intake of energy and proteins in the 1997-1998 Dutch Food Consumption Survey; average (standard deviation).^a

age (years)	energy (MJ/d)		proteins (g/d)		proteins (% of total energy intake)	
	M	F	M	F	M	F
1 to 3	6.1 (1.5)	5.4 (1.3)	50 (13)	45 (13)	14.0 (2.7)	14.2 (2.9)
4 to 6	6.9 (1.4)	6.6 (1.3)	56 (14)	53 (14)	13.6 (2.7)	13.6 (2.3)
7 to 9	8.4 (1.8)	7.6 (1.6)	66 (15)	61 (16)	13.5 (2.7)	13.5 (2.6)
10 to 12	9.4 (2.3)	8.6 (1.8)	74 (20)	66 (15)	13.4 (2.4)	13.0 (2.3)
13 to 15	10.9 (2.7)	8.7 (1.9)	84 (22)	70 (17)	13.1 (2.4)	13.7 (2.5)
16 to 18	11.6 (3.3)	9.1 (2.3)	90 (26)	72 (20)	13.3 (2.6)	13.4 (2.6)
19 to 21	11.9 (3.3)	8.6 (2.3)	98 (31)	70 (20)	13.9 (2.5)	14.0 (3.4)
22 to 49	11.2 (2.9)	8.5 (2.3)	95 (28)	76 (21)	14.5 (3.0)	15.3 (3.7)
50 to 65	10.4 (2.7)	7.8 (2.3)	95 (25)	76 (21)	15.6 (3.3)	16.9 (4.0)
≥ 65	9.4 (2.4)	7.5 (1.9)	86 (24)	73 (18)	15.5 (3.3)	16.7 (3.9)
≥ 75	9.1 (2.5)	7.5 (1.8)	82 (25)	72 (19)	15.3 (3.4)	16.3 (3.4)
pregnancy	-	8.9 (2.3)	-	80 (23)	-	15.3 (3.1)

^a M = boys and men; F = girls and women

Table C2 Intake of fats and linoleic acid, expressed as a percentage of total energy intake, in the 1997-1998 Dutch Food Consumption Survey; average (standard deviation).^a

age (years)	fats		linoleic acid	
	M	F	M	F
1 to 3	30.9 (6.2)	30.4 (5.6)	4.8 (2.1)	4.8 (1.9)
4 to 6	32.1 (6.1)	31.6 (5.7)	5.4 (1.7)	5.2 (1.8)
7 to 9	33.8 (6.1)	34.4 (6.6)	5.6 (1.7)	5.6 (2.0)
10 to 12	35.1 (6.2)	34.8 (5.8)	5.7 (1.9)	5.6 (2.1)
13 to 15	35.5 (5.5)	35.9 (5.9)	6.0 (2.2)	5.9 (2.1)
16 to 18	35.4 (6.1)	35.5 (6.3)	6.1 (2.3)	5.5 (2.1)
19 to 21	36.0 (6.6)	35.1 (5.7)	6.0 (2.1)	5.5 (1.9)
22 to 49	36.5 (6.5)	37.0 (6.8)	5.9 (2.1)	5.7 (2.2)
50 to 65	36.7 (6.3)	36.9 (7.3)	6.1 (2.5)	5.8 (2.7)
≥ 65	36.7 (6.5)	37.0 (7.0)	6.3 (2.4)	6.2 (2.8)
≥ 75	38.8 (7.2)	37.8 (7.5)	7.0 (3.7)	6.3 (3.0)
pregnancy	-	35.9 (6.2)	-	5.1 (2.0)

^a M = boys and men; F = girls and women

Table C3 Intake of saturated fatty acids, monounsaturated fatty acids and polyunsaturated fatty acids, expressed as a percentage of total energy intake, in the 1997-1998 Dutch Food Consumption Survey; average (standard deviation).^a

age (years)	saturated fatty acids		monounsaturated fatty acids		polyunsaturated fatty acids	
	M	F	M	F	M	F
1 to 3	12.7 (2.7)	12.5 (2.9)	10.5 (2.6)	10.3 (2.3)	5.7 (2.3)	5.6 (2.0)
4 to 6	12.8 (2.8)	12.6 (2.6)	11.0 (2.6)	10.9 (2.5)	6.2 (1.8)	6.0 (1.9)
7 to 9	13.4 (2.8)	13.6 (2.9)	11.8 (2.7)	11.9 (2.9)	6.4 (1.8)	6.6 (2.1)
10 to 12	13.6 (2.9)	13.7 (2.6)	12.6 (2.9)	12.3 (2.7)	6.7 (2.0)	6.6 (2.1)
13 to 15	13.4 (2.4)	14.2 (2.9)	12.8 (2.7)	12.5 (2.5)	7.0 (2.3)	6.9 (2.2)
16 to 18	13.6 (2.9)	14.0 (2.8)	12.4 (2.5)	12.6 (3.0)	7.0 (2.4)	6.5 (2.2)
19 to 21	13.8 (3.0)	13.6 (3.1)	12.8 (2.8)	12.7 (2.8)	7.0 (2.2)	6.4 (2.0)
22 to 49	14.2 (3.1)	14.6 (3.4)	12.9 (2.9)	13.2 (3.0)	6.9 (2.1)	6.8 (2.3)
50 to 65	14.5 (3.3)	14.8 (3.7)	12.7 (2.7)	12.8 (3.2)	7.1 (2.6)	6.8 (2.8)
≥ 65	14.6 (3.5)	15.0 (3.8)	12.3 (2.7)	12.4 (2.9)	7.3 (2.4)	7.1 (2.8)
≥ 75	15.6 (3.8)	15.8 (4.1)	12.6 (3.0)	12.3 (3.0)	7.9 (3.6)	7.2 (3.1)
pregnancy	-	14.8 (2.9)	-	12.4 (2.7)	-	6.2 (2.2)

^a M = boys and men; F = girls and women

Table C4 Intake of carbohydrates, expressed as a percentage of total energy intake, in the 1997-1998 Dutch Food Consumption Survey; average (standard deviation).^a

age (years)	carbohydrates	
	M	F
1 to 3	55.0 (6.1)	55.4 (6.7)
4 to 6	54.3 (6.6)	54.7 (6.4)
7 to 9	52.7 (6.6)	52.0 (7.3)
10 to 12	51.5 (6.4)	52.1 (6.2)
13 to 15	51.2 (5.8)	50.3 (6.5)
16 to 18	49.5 (6.6)	50.3 (7.1)
19 to 21	46.9 (6.9)	50.0 (7.1)
22 to 49	44.6 (7.6)	45.0 (7.8)
50 to 65	42.4 (7.1)	42.7 (7.6)
≥ 65	42.6 (7.4)	44.0 (7.4)
≥ 75	42.7 (8.2)	43.7 (8.3)
pregnancy	-	48.8 (6.9)

^a M = boys and men; F = girls and women

Table C5 Average intake of saturated fatty acids (g/day) by middle-aged men in the Seven Countries Study (Vir97).

cohort	country	population	saturated fatty acid														total of saturated fatty acids		
			C8:0	C10:0	C12:0	C14:0	C15:0	C16:0	C17:0	C18:0	C20:0	C22:0	C24:0	g/d	energy % ^a				
VS		railway employees	0.5	1.3	1.8	5.8	0.7	30.0	0.7	14.0	0.3	0.3	0.1	0.1	0.3	0.3	0.1	55.5	21.2
Finland		eastern part	1.3	3.3	4.3	14.0	1.6	41.0	0.9	22.0	0.4	0.3	0.1	0.1	0.3	0.3	0.1	89.2	22.6
"		western part	0.4	2.1	3.4	11.0	1.1	35.0	0.7	18.0	0.3	0.4	0.2	0.2	0.4	0.4	0.2	72.6	18.4
Netherlands		Zutphen	0.6	1.3	2.2	8.0	0.8	30.0	0.6	15.0	1.0	1.1	0.5	0.5	1.0	1.1	0.5	61.1	20.1
Italy		Crevalcore	0.5	0.8	1.1	4.2	0.5	31.0	0.5	15.0	0.5	0.4	0.2	0.2	0.4	0.4	0.2	54.7	13.4
"		Montegiorgio	0.1	0.3	0.3	1.3	0.1	19.0	0.3	9.4	0.3	0.2	0.1	0.1	0.3	0.2	0.1	31.4	9.6
"		railway employees Rome	0.2	0.4	0.7	2.4	0.3	17.0	0.3	6.2	0.3	0.2	0.1	0.1	0.3	0.2	0.1	28.1	9.4
Greece		Corfu	0.2	0.4	0.3	1.1	0.2	16.0	0.1	3.1	0.4	0.2	0.1	0.1	0.4	0.2	0.1	22.1	7.2
"		Crete	0.3	0.7	0.5	1.8	0.3	18.0	0.2	5.6	0.6	0.3	0.1	0.1	0.6	0.3	0.1	28.4	8.9
Kroatia		Dalmatia	0.3	0.5	0.5	2.5	0.3	24.0	0.4	10.0	0.5	0.3	0.2	0.2	0.5	0.3	0.2	39.5	9.3
"		Slavonia	0.2	0.5	0.6	3.7	0.5	42.0	0.5	20.0	0.2	0.2	0.1	0.1	0.2	0.2	0.1	68.5	16.5
Servia		Belgrade	0.7	1.2	1.3	5.6	0.8	31.0	0.7	15.0	0.4	0.4	0.2	0.2	0.4	0.4	0.2	57.3	18.4
"		Velika-Krsna	0.9	1.3	1.5	5.8	0.8	29.0	0.5	12.0	0.1	0.2	0.1	0.1	0.1	0.2	0.1	52.2	13.6
"		Zrenjanin	0.1	0.3	0.4	2.6	0.2	33.0	0.5	17.0	0.4	0.2	0.1	0.1	0.4	0.2	0.1	54.8	15.1
Japan		Tanushimaru	0.1	0.0	0.1	0.8	0.1	6.5	0.1	2.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10.0	3.6
"		Ushibuka	0.0	0.0	0.2	1.0	0.1	9.2	0.2	3.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	14.0	5.2
		lowest value	0.0	0.0	0.1	0.8	0.1	6.5	0.1	2.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10.0	3.6
		highest value	1.3	3.3	4.3	14.0	1.6	42.0	0.9	22.0	1.0	1.1	0.5	0.5	1.0	1.1	0.5	89.2	22.6

^a Calculated as the sum of the average intake of specific saturated fatty acids (in gram per dag), divided by the total intake of fat (in gram per day), and multiplied with total fat intake (in energy percent).

Table C6 Average intake of monounsaturated fatty acids (MUFA) (g/day) by middle-aged men in the Seven Countries Study (Viri97).

cohort	cis-MUFA										total cis-MUFA			trans-MUFA			total trans-MUFA	
	population	C14:1	C16:1	C17:1	C18:1	C20:1	C22:1	C24:1	g/d	energie % ^a	C16:1	C18:1	g/d	energie % ^b				
VS	railway employees	0.8	3.0	0.4	44.0	0.4	0.1	0.0	48.7	18.6	0.3	3.9	4.2	1.6				
Finland	eastern part	1.3	3.4	0.0	49.0	0.6	0.2	0.1	54.6	13.8	0.8	4.9	5.7	1.4				
"	western part	1.1	2.8	0.3	44.0	0.7	0.3	0.0	49.2	12.5	0.6	3.6	4.2	1.1				
Netherlands	Zutphen	0.6	4.3	0.3	37.0	4.3	2.9	0.2	49.6	16.3	2.6	5.5	8.1	2.7				
Italy	Crevalcore	0.4	2.7	0.0	68.0	1.0	0.3	0.0	72.4	17.7	0.0	1.1	1.1	0.3				
"	Montegiorgio	0.2	1.7	0.0	47.0	0.9	0.4	0.0	50.2	15.4	0.0	0.4	0.4	0.1				
"	railway employees Rome	0.4	1.6	0.2	51.0	0.8	0.3	0.0	54.3	18.1	0.0	0.7	0.7	0.2				
Greece	Corfu	0.1	1.4	0.1	61.0	0.3	0.1	0.0	63.0	20.4	0.0	0.2	0.2	0.1				
"	Crete	0.2	1.3	0.2	82.0	0.4	0.1	0.0	84.2	26.4	0.0	0.4	0.4	0.1				
Kroatia	Dalmatia	0.3	2.8	0.2	73.0	1.3	0.2	0.1	77.9	18.4	0.0	1.1	1.1	0.3				
"	Slavonia	0.4	5.3	0.0	73.0	2.0	0.3	0.1	81.1	19.5	0.0	1.2	1.2	0.3				
Servia	Belgrade	0.6	3.0	0.4	49.0	1.1	0.1	0.0	54.2	17.4	0.3	2.0	2.3	0.7				
"	Velika-Krsna	0.6	2.6	0.2	38.0	0.7	0.3	0.0	42.4	11.1	0.1	2.2	2.3	0.6				
"	Zrenjanin	0.3	3.8	0.4	59.0	1.4	0.3	0.0	65.2	17.9	0.0	1.3	1.3	0.4				
Japan	Tanushimaru	0.1	0.8	0.0	8.0	0.0	0.8	0.2	9.9	3.6	0.1	0.1	0.2	0.1				
"	Ushibuka	0.2	1.6	0.0	15.0	0.0	0.3	0.1	17.2	6.4	0.0	0.3	0.3	0.1				
lowest value		0.1	0.8	0.0	8.0	0.0	0.1	0.0	9.9	3.6	0.0	0.1	0.2	0.1				
highest value		1.3	5.3	0.4	82.0	4.3	2.9	0.2	84.2	26.4	2.6	5.5	8.1	2.7				

^a Calculated as the sum of the average intake of specific *cis* monounsaturated fatty acids (in gram per dag), divided by the total intake of fat (in gram per day), and multiplied with total fat intake (in energy percent).

^b Calculation similar to that of *cis* monounsaturated fatty acids.

Table C7 Average intake of polyunsaturated fatty acids (PUFA) (g/day) by middle-aged men in the Seven Countries Study (Vri97).

cohort	cis-polyunsaturated fatty acids													trans-C18:2				
	population	n-3			n-6						other			total		ener-g/d	ener-gy% ^b	
		C18:3	C18:4	C20:3	C20:5	C22:3	C22:5	C22:6	C18:2	C18:3	C20:4	C22:4	C20:2	C22:2	g/d			ener-gy% ^a
VS	railway employees	2.1	0.3	0.0	0.1	0.0	0.1	0.0	17.0	0.2	0.4	0.1	0.0	0.0	20.3	7.7	0.9	0.3
Finland	eastern part	2.5	0.6	0.1	0.5	0.0	0.2	0.4	8.0	0.3	0.4	0.1	0.0	0.0	13.1	3.3	1.4	0.4
"	western part	1.7	0.6	0.1	0.2	0.0	0.1	0.2	8.7	0.1	0.4	0.0	0.0	0.0	12.1	3.1	0.3	0.1
Netherlands	Zutphen	2.2	0.2	0.0	0.3	0.1	0.1	0.1	12.0	0.1	0.5	0.1	1.5	1.2	18.4	6.0	0.6	0.2
Italy	Crevalcore	1.2	0.6	0.1	0.1	0.0	0.1	0.2	17.0	0.0	0.4	0.1	0.4	0.0	20.2	5.0	0.0	0.0
"	Montegiorgio	1.0	0.0	0.1	0.1	0.2	0.1	0.2	12.0	0.0	0.2	0.1	0.6	0.0	14.6	4.5	0.1	0.0
"	railway employees Rome	0.8	0.0	0.0	0.1	0.1	0.1	0.1	8.1	0.0	0.3	0.0	0.2	0.0	9.8	3.3	0.0	0.0
Greece	Corfu	1.1	0.1	0.0	0.2	0.0	0.0	0.6	13.0	0.0	0.1	0.0	0.0	0.0	15.1	4.9	0.0	0.0
"	Crete	1.2	0.0	0.0	0.1	0.0	0.0	0.2	11.0	0.0	0.2	0.0	0.0	0.0	12.7	4.0	0.0	0.0
Kroatia	Dalmatia	1.6	0.9	0.1	0.6	0.1	0.2	1.1	17.0	0.0	0.3	0.1	0.0	0.0	22.0	5.2	0.0	0.0
"	Slavonia	1.4	1.5	0.2	0.2	0.2	0.2	0.3	16.0	0.0	0.5	0.1	0.0	0.0	20.6	4.9	0.0	0.0
Servia	Belgrade	2.0	0.6	0.1	0.1	0.1	0.1	0.2	22.0	0.1	0.3	0.1	0.0	0.0	25.7	8.3	0.0	0.0
"	Velika-Krsna	1.1	0.7	0.1	0.1	0.0	0.1	0.1	13.0	0.0	0.3	0.1	0.0	0.0	15.6	4.1	0.0	0.0
"	Zrenjanin	1.3	0.7	0.1	0.1	0.0	0.2	0.2	19.0	0.0	0.4	0.1	0.0	0.0	22.1	6.1	0.0	0.0
Japan	Tanushimaru	1.0	1.0	0.3	0.5	0.2	0.1	0.7	8.0	0.0	0.1	0.0	0.0	0.0	11.9	4.3	0.0	0.0
"	Ushibuka	1.3	0.8	0.3	0.8	0.1	0.3	1.1	8.2	0.1	0.1	0.1	0.0	0.0	13.2	4.9	0.0	0.0
lowest value		0.8	0.0	0.0	0.1	0.0	0.0	0.0	8.0	0.0	0.1	0.0	0.0	0.0	9.8	3.1	0.0	0.0
highest value		2.5	1.5	0.3	0.8	0.2	0.3	1.1	22.0	0.3	0.5	0.1	1.5	1.2	25.7	8.3	1.4	0.4

^a Calculated as the sum of the average intake of specific cis polyunsaturated fatty acids (in gram per dag), divided by the total intake of fat (in gram per day), and multiplied with total fat intake (in energy percent).

^b Calculation similar to that of cis polyunsaturated fatty acids.

Table C8 Average intake and distribution in the intake of alpha linolenic acid in adult men.

country	age (years)	ref ^a	intake of alpha linolenic acid								
			average	standard deviation	percentiles of intake						
					2½	10	25	50	75	90	97½
<i>study results, in grams per day^{cb}:</i>											
Belgium	18-65	Hul99	1.7	0.8	-	0.9	-	1.6	-	2.6	-
Denmark	19-64	Hul99	2.2	0.9	-	1.3	-	2.1	-	3.2	-
Germany	19-64	Hul99	0.9	0.5	-	0.5	-	0.8	-	1.6	-
Germany	19-24	Ado95	-	-	0.89	-	1.49	1.86	2.36	-	3.82
Germany	25-50	Ado95	-	-	0.88	-	1.41	1.75	2.19	-	3.40
Germany	51-64	Ado95	-	-	0.85	-	1.35	1.70	2.10	-	3.27
Germany	≥ 65	Ado95	-	-	0.83	-	1.35	1.65	1.97	-	3.04
Finland	25-64	Hul99	1.8	0.9	-	0.9	-	1.6	-	3.0	-
France	19-64	Hul99	0.6	0.3	-	0.4	-	0.6	-	0.9	-
Greece	23-64	Hul99	0.6	0.5	-	0.2	-	0.5	-	1.2	-
Iceland	19-64	Hul99	2.5	1.5	-	1.0	-	2.0	-	4.5	-
the Netherlands	19-64	Hul99	1.7	0.7	-	0.9	-	1.6	-	2.7	-
the Netherlands	71.5±5.3	Vos96	1.30	0.46	-	-	-	1.24	-	-	-
the Netherlands	75.1±4.6	Vos96	1.21	0.52	-	-	-	1.11	-	-	-
Norway	19-64	Hul99	1.6	1.2	-	0.5	-	1.3	-	3.1	-
Portugal	38	Hul99	0.7	0.4	-	0.4	-	0.7	-	1.2	-
United States	adults	Ben99	1.59	0.01	-	0.63	-	1.36	-	2.63	-
Switzerland	19-64	Hul99	1.4	0.7	-	0.6	-	1.2	-	2.3	-

study results as a percentage of total energy intake:

the Netherlands	71.5±5.3	Vos96	0.5	0.1	-	-	-	-	-	-	-
the Netherlands	75.1±4.6	Vos96	0.5	0.2	-	-	-	-	-	-	-
United States	adults	Ben99	0.59	0.003	-	0.34	-	0.56	-	0.91	-

^a Ado95: Adolf T, Schneider R, Eberhardt W, e.a. Ergebnisse der Nationalen Verzehrsstudie (1985-1988) über die Lebensmittel- und Nährstoffaufnahme in der Bundesrepublik Deutschland. In: Kübler W, Anders HJ, Heeschen W: Band XI der VERA-Schriftenreihe. Wissenschaftlicher Fachverlag Dr Fleck, Niederkleen 1995, pp 88-91.

Ben99: Benisek D, Kyle D. Socioeconomic differences in the consumption of polyunsaturated fatty acids in the United States. J Am Coll Nutr 1999; 18: 543-4 abstract 87.

Hul99: Hulshof KFAM, van Erp-Baart MA, Anttolainen M, e.a. Intake of fatty acids in Western Europe with emphasis on *trans* fatty acids: the TRANSFAIR study. Eur J Clin Nutr 1999; 53: 143-57.

Vos96: Voskuil DW, Feskens EJM, Katan MB, Kromhout D. Intake and sources of α -linolenic acid in Dutch elderly men. Eur J Clin Nutr 1996; 50: 784-7.

^b Based on the estimated average requirement for energy, derived in section 2, an adequate intake of alpha-linolenic acid of one percent of total energy intake is equivalent to a daily intake of 3.4 grams for men aged from 19 to 30, 3.2 grams for men aged 31 to 50, 2.9 grams for men aged from 50 to 70 and 2.4 grams for men of more than 70 years of age.

Table C9 Average intake and distribution in the intake of alpha linolenic acid in adult women.

country	age (years)	ref ^a	intake of alpha linolenic acid								
			average	standard deviation	percentiles of intake						
					2½	10	25	50	75	90	97½
<i>study results, in grams per day^b:</i>											
Belgium	18-65	Hul99	1.4	0.6	-	0.7	-	1.3	-	2.1	-
Denmark	19-64	Hul99	2.1	1.0	-	1.0	-	2.0	-	3.3	-
Germany	19-64	Hul99	0.7	0.4	-	0.4	-	0.6	-	1.2	-
Germany	19-24	Ado95	-	-	0.66	-	1.18	1.47	1.91	-	2.99
Germany	25-50	Ado95	-	-	0.69	-	1.16	1.47	1.78	-	2.85
Germany	51-64	Ado95	-	-	0.73	-	1.17	1.44	1.76	-	2.72
Germany	≥ 65	Ado95	-	-	0.69	-	1.13	1.42	1.71	-	2.81
Finland	25-64	Hul99	1.3	0.6	-	0.6	-	1.3	-	2.1	-
France	19-64	Hul99	0.5	0.2	-	0.3	-	0.4	-	0.8	-
Greece	23-64	Hul99	0.7	0.9	-	0.2	-	0.5	-	1.3	-
Iceland	19-64	Hul99	1.4	0.9	-	0.6	-	1.2	-	2.5	-
the Netherlands	19-64	Hul99	1.2	0.6	-	0.7	-	1.1	-	2.0	-
Norway	19-64	Hul99	1.0	0.7	-	0.4	-	0.8	-	2.0	-
United States	adults	Ben99	1.11	0.01	-	0.45	-	0.96	-	1.95	-
Switzerland	19-64 years of age	Hul99	1.0	0.5	-	0.5	-	0.9	-	1.7	-

study results as a percentage of total energy intake:

United States	adults	Ben99	0.62	0.004	-	0.34	-	0.57	-	0.98	-
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^a Ado95: Adolf T, Schneider R, Eberhardt W, e.a. Ergebnisse der Nationalen Verzehrsstudie (1985-1988) über die Lebensmittel- und Nährstoffaufnahme in der Bundesrepublik Deutschland. In: Kübler W, Anders HJ, Heeschen W: Band XI der VERA-Schriftenreihe. Wissenschaftlicher Fachverlag Dr Fleck, Niederkleen 1995 pp 88-91.

Ben99: Benisek D, Kyle D. Socioeconomic differences in the consumption of polyunsaturated fatty acids in the United States. J Am Coll Nutr 1999; 18: 543-4 abstract 87.

Hul99: Hulshof KFAM, van Erp-Baart MA, Anttolainen M, e.a. Intake of fatty acids in Western Europe with emphasis on *trans* fatty acids: the TRANSFAIR study. Eur J Clin Nutr 1999; 53: 143-57.

Vos96: Voskuil DW, Feskens EJM, Katan MB, Kromhout D. Intake and sources of α -linolenic acid in Dutch elderly men. Eur J Clin Nutr 1996; 50: 784-7.

^b Based on the estimated average requirement for energy, derived in section 2, an adequate intake of alpha-linolenic acid of one percent of total energy intake is equivalent to a daily intake of 2.7 grams for women aged from 19 to 30, 2.6 grams for women aged 31 to 50, 2.4 grams for women aged from 50 to 70 and 2.1 grams for women of more than 70 years of age.