Assessing obesity: classification and epidemiology

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Obesity is generally defined as a body mass index (BMI) of 30 kg/m^2 and higher. Overweight is defined as a BMI between 25 and 30 kg/m^2. The prevalence varies considerably between countries, and between regions within countries. It is estimated that more than half of adults aged 35–65 living in Europe are either overweight or obese. Overweight is more common among men than among women but obesity is more common among women. The prevalence of obesity in Europe is probably in the order of 10–20% in men and 15–25% in adult women. In most European countries who have reliable data on time-trends the prevalence of obesity seems to be increasing. In most European countries, obesity is usually inversely associated with socio-economic status, particularly among women. New classifications of overweight may be based on cut-off points for simple anthropometric measures which reflects both total adiposity as well as abdominal fatness.

How to measure obesity

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When we speak about the prevalence of obesity in populations we actually mean the fraction of people who have an excess storage of body fat. In adult men with an average weight, the percentage body fat is in the order of 15–20%. In women this percentage is higher (about 25–30%). Because differences in weight between individuals are only partly due to variations in body fat, many people object to the use of weight or indices based on height and weight (such as the body mass index, BMI) to discriminate between overweight and normal weight people. There are always examples which illustrate the inappropriate use of body mass index in certain individuals, such as an identical body mass index in a young male body builder and a middle aged obese women. However, despite these obvious extremes, there is a very good correlation between BMI (weight divided by height squared) and the percentage of body fat

Table 1 Cut-off points proposed by a WHO Expert Committee for the classification of overweight[3]

Body mass index	WHO classification	Popular description
$< 18.5\ kg/m^2$	Underweight	Thin
$18.5–24.9\ kg/m^2$	—	'Healthy', 'normal' or 'acceptable' weight
$25.0–29.9\ kg/m^2$	Grade 1 overweight	Overweight
$30.0–39.9\ kg/m^2$	Grade 2 overweight	Obesity
$\geq 40.0\ kg/m^2$	Grade 3 overweight	Morbid obesity

in large populations. Deurenberg *et al.*[1] established that one can quite accurately estimate the body fat percentage in adults with the following equation:

$$\text{Body fat\%} = 1.2\ (\text{Body Mass Index}) + 0.23\ (\text{age}) - 10.8\ (\text{gender}) - 5.4$$

where gender=1 for men and gender=0 for women.

About 80% of the variation in body fat between (Dutch) individuals could be explained by this formula. The standard error of estimate was about 4%. It follows from this equation that, for a given height and weight, the body fat percentage is about 10% higher in women compared to men. In addition, people get fatter when they get older even when their body weights are stable. The good correlation between BMI and fat percentage implies that, in populations, BMI can be used to classify people in terms of excess body fat. In practice, people or populations are usually not classified on the basis of the body fat percentage but on the basis of their BMI. Usually, the same cut-off points are applied for men and women and for different age groups. This is done because the relationships between BMI and mortality are similar (i.e. the relative mortality associated with obesity is similar in men and women, in most age groups the absolute mortality is much lower). The same relative risk and lower absolute risk associated with overweight and obesity among women compared to men implies that women can probably tolerate body fat better than men. The reason in women could be that their excess body fat is usually distributed as subcutaneous fat and mainly peripherally (thighs, buttocks, breasts) and in men there is a relative excess of body fat stored in the abdominal cavity and as abdominal subcutaneous fat. It has been suggested that optimal BMI (i.e. the BMI associated with lowest relative risk) increases with age[2]. The reasons why older people seem to tolerate an excess body fat better than younger people are manifold, and range from selective survival to decreased lipolysis of adipose tissue in older people. The cut-off points have recently been proposed by a WHO Expert Committee for the classification of overweight (Table 1)[3]. These figures apply to both men and women and to all adult age-groups. There are limitations in the interpretation of body mass index in very old subjects as well as in

certain ethnic groups with deviating body proportions (e.g. in populations where stunted growth is common, in those with relatively short leg length compared to sitting height).

How to measure fat distribution

Since the pioneering work of Jean Vague in the 1940s, it has slowly become accepted that different body morphology or types of fat distribution are independently related to the health risks associated with obesity[4]. Starting with Jean Vague's brachio-femoral adipo-muscular ratio as an index of fat distribution (which was based on ratios of skinfolds and circumferences of the arms and thighs), more recent indices have been adopted to predict specifically intra-abdominal fat. The most popular among all measures is the waist/hip circumference ratio. The simplest of these measures is the waist circumference, which has been suggested to predict intra-abdominal fat at least as accurately as the waist/hip ratio[5] and to predict levels of cardiovascular risk factors and disease as well as BMI and waist/hip ratio[6]. It has also been suggested that waist circumference could possibly be used to replace classifications based on BMI and the waist/hip circumference ratio[7]. More complex measures, such as the sagittal abdominal diameter, the ratio of waist/thigh circumference, the ratio of waist/height or the conicity index, have also been proposed to perform even better than waist circumference for one or more of these purposes. However, the differences among these measures are small and the use of ratios may complicate the interpretation of associations with disease and their consequences for public health measures. For instance, the waist/height ratio may be a better predictor of morbidity because the waist is positively associated with disease and because height, for reasons unrelated to body composition or fat distribution, is inversely associated with disease.

Replacing BMI and waist/hip ratio by simple cut-off points which are optimal for each sex, age group, population and relationship with specific diseases may, however, be too simple. Still, as suggested by Lean

Table 2 Sex-specific cut-off points for waist circumference. Level 1 was initially based on replacing the classification of overweight (BMI $\geqslant 25\ kg/m^2$) in combination with high waist/hip ratio (WHR $\geqslant 0.95$ in men and $\geqslant 0.80$ in women). Level 2 was based on classification of obesity (BMI $\geqslant 30\ kg/m^2$) in combination with high waist/hip ratio[4,7]

	Level 1 ('alerting zone')	Level 2 ('action level')
Men	$\geqslant 94$ cm (~ 37 inches)	$\geqslant 102$ cm (~ 40 inches)
Women	$\geqslant 80$ cm (~ 32 inches)	$\geqslant 88$ cm (~ 35 inches)

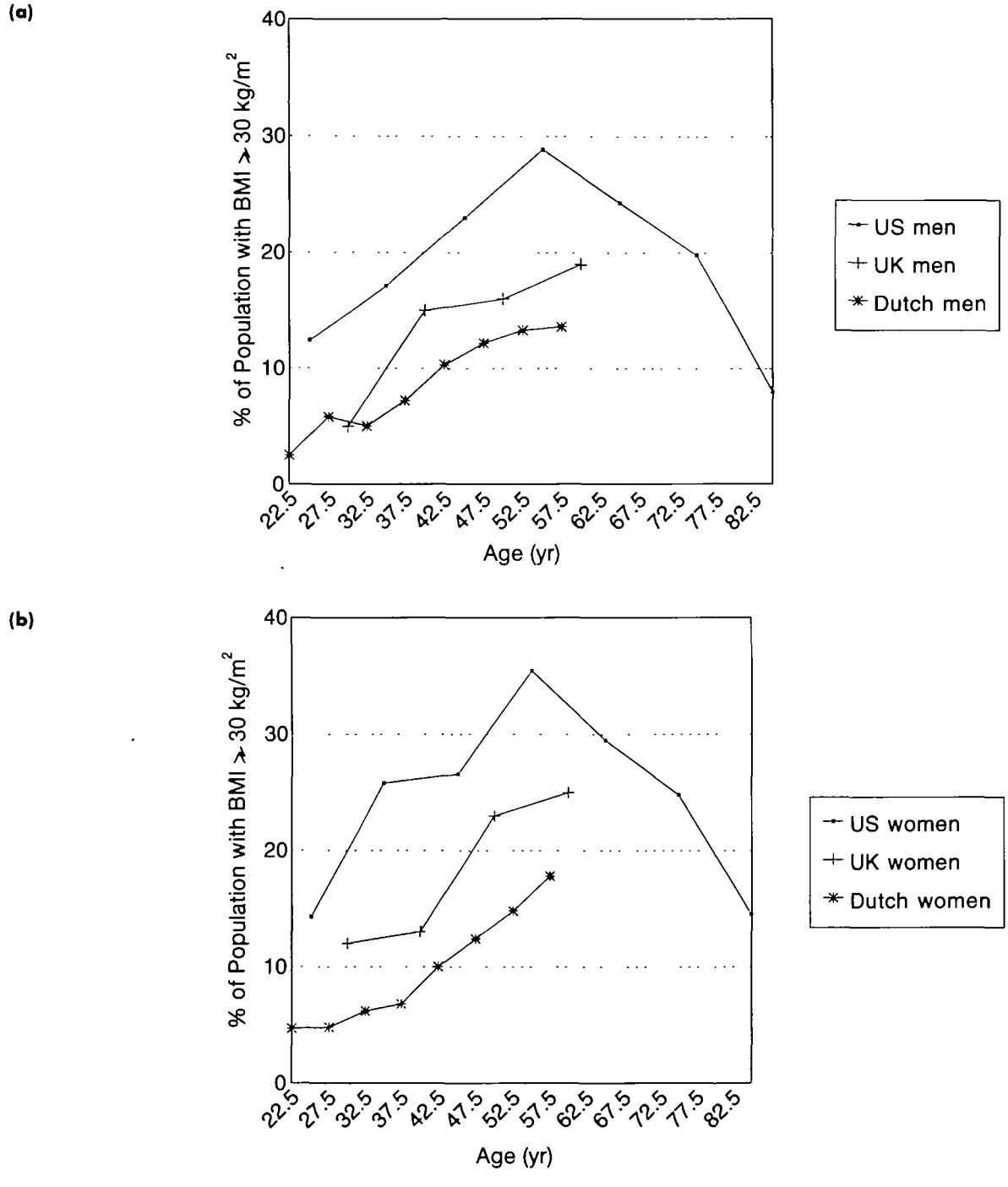

Fig. 1 (a) and (b) Prevalence of obesity (BMI > 30 kg/m²) in men (A) and women (B) by age in the US (NHANES III, 1988–1994), in the UK (national survey 1992) and in The Netherlands (about 13000 people measured in 1993–1995 in three towns).

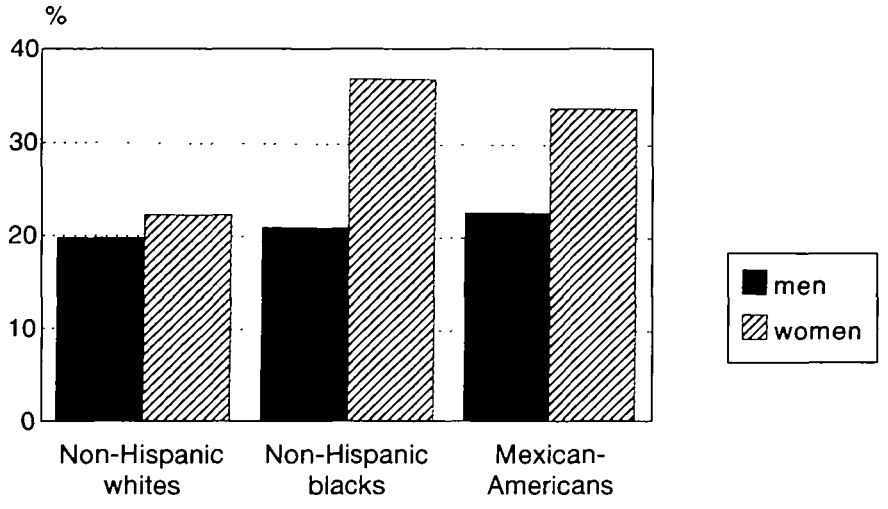

Fig. 2 Prevalence of overweight (BMI > 30 kg/m²) in different race–ethnic groups in the US in 1991 (midpoint of NHANES III).

et al.[7], some cut-off points may be of guidance in interpreting values of waist circumference for adults (Table 2). Other cut-off points, based on classification of subjects on a 'critical level' of intra-abdominal fat, have been proposed by investigators from Quebec[8].

Who is obese?

Very little is known about the factors that may explain the large differences between populations in the distributions of BMI (see next section). Obviously, overweight in individuals in any population is the result of a long-term positive energy balance. Just to say that overweight is characterised by physical inactivity or ingestion of large quantities of food is an oversimplification. Several epidemiological studies have shown that the following factors are associated with overweight in the population.

Demographic factors

Age: overweight increases with age, at least up till age 50–60 years in men and women. Figure 1a,b shows the relation between age and prevalence of obesity in the UK (1992 data), The Netherlands (1993–1995 data) and the USA (NHANES III 1988–1994)[9–11].

Gender: women have generally higher prevalences of obesity compared to men especially when older than 50 years of age.

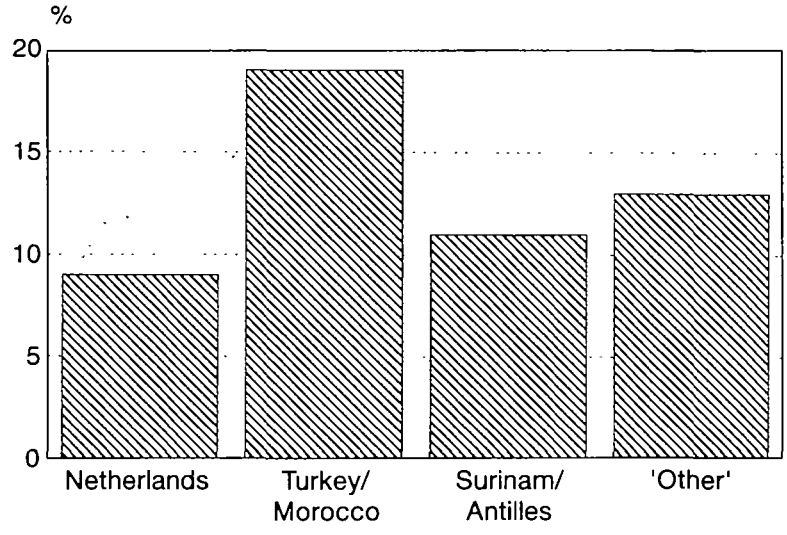

Fig. 3 Prevalence of obesity in 4450 children aged 4–15 years living in The Netherlands in 1993/1994 according to the 97th percentile values of BMI for age in French children (Rolland Cachera *et al.*, 1982). Stratified by nationality of the father.

Ethnicity: there are large, usually unexplained, variations between ethnic groups. Figure 2 shows that in the US there is little variation for men by race–ethnic group but much larger differences for women by race–ethnic group. Figure 3 shows the prevalence of overweight among Dutch children by ethnic group and illustrates the higher prevalence among children of immigrants compared to 'native' Dutch children[12].

Socio-cultural factors

Educational level and income: in industrialized countries, there is a higher prevalence of overweight in those with lower education and/or income.

Marital status: Usually overweight increases after marriage.

Biological factors

Parity: it has been claimed that BMI increases with increasing number of children, but recent evidence suggests that this contribution is, on average, likely to be less than 1 kg per pregnancy. Many study designs confound the changes in weight with aging and parity.

Behavioural factors

Dietary intake: although it is clear that nutrition is of critical importance in establishing a positive energy balance, research on this topic has not been easy to interpret because of confounding factors including increased under-reporting with increasing degrees of obesity. Another reason may be that only small deviations in energy balance are necessary to yield large differences in body weight in the long term. The methodological errors in determining energy intake may be too large to allow detection of the nutritional determinants of obesity. In particular, the fat percentage of the diet has been proposed to be associated with higher prevalence of obesity, although also on this topic the epidemiological evidence may be flawed or biased[13].

Smoking: smoking lowers body weight and cessation of smoking increases body weight. The associations between smoking and obesity may, however, vary considerably among populations[14].

Alcohol consumption: the effect is unclear in most populations. Moderate alcohol consumption is sometimes associated with higher body mass index.

Physical activity: those who remain or become inactive are usually heavier then those who are physically active. Similar limitations apply as for the interpretation of the evidence of nutritional determinants of obesity: methodological problems, such as confounding and biased reporting as well as measurement error, make it difficult to interpret the literature.

Prevalence of obesity in Europe

Obesity, defined as a body mass index greater than 30 kg/m^2, is a common condition in Europe and the US[15]. In order to make a comparison possible between countries, it is necessary to compare population-based data on measured height and weight in which identical protocols for measurement were applied and which were collected in the same period. The most comprehensive data on the prevalence of obesity in Europe are from the WHO MONICA study[16]. Most of these data were collected between 1983 and 1986. The populations studied, however, do not necessarily represent the population as a whole.

Tables 3 and 4 show the age-standardised prevalence of overweight and obesity in 39 European centres participating in this study[16]. Only in

Table 3 Prevalence of overweight (BMI 25–30 kg/m²) and obesity (BMI ⩾30 kg/m²) in European men aged 35–64 years. Data from the WHO MONICA (first round 1983–1986) populations[16]

Country	Center	Prevalence		
		Overweight	Obese	Overweight+obese
Iceland	Iceland	44	11	55
Sweden	Northern Sweden	45	12	57
Sweden	Gothenburg	44	7	51
Finland	Kuopio Province	50	18	68
Finland	North Karelia	51	17	68
Finland	Turku-Loima	49	19	68
Denmark	Glostrup	44	11	55
UK	Glasgow	46	11	57
UK	Belfast	45	11	56
Germany	Bremen	53	14	67
Germany	Rhein-Neckar	52	14	66
Germany	Augsburg	56	18	74
Germany	Augsburg (rural)	56	20	76
Germany	Halle County	51	18	69
Germany	Karl-Marx-Stadt	50	15	65
Germany	Cottbus County	51	17	68
Germany	'Rest of DDR MONICA'	54	19	73
Belgium	Ghent	50	11	61
Belgium	Charleroi	48	20	68
Belgium	Luxembourg Province	45	14	59
France	Lille	44	14	58
France	Bas Rhin/Strassbourg	52	22	74
France	Haute Garonne/Toulouse	51	9	60
Switzerland	Vaud-Fribourg	49	12	61
Switzerland	Ticino	51	19	70
Russia	Novosibirsk (2 samples)	46	14	60
Russia	Moscow (2 samples)	45	13	58
Lithuania	Kaunas	54	22	76
Poland	Warsaw	48	17	65
Poland	Tarnobrzeg Voivodship	39	13	52
Czech Rep.	'Czechoslovakia'	51	21	72
Hungary	Pecs	42	19	61
Hungary	Budapest	46	15	61
Serbia	Novi Sad	50	18	68
Spain	Catalonia	57	9	66
Italy	Area Brianza	44	11	55
Italy	Friuli	49	17	66
Italy	Area Latina	52	18	70
Malta	Malta	46	25	71
95% CI of mean		46.2–51.4	14.2–16.8	62.1–66.3
Mean ± SD		48.8 ± 4.1	15.5 ± 4.2	64.2 ± 6.8

three centres was the prevalence of obesity slightly lower than 10% (Gothenburg, Sweden (men and women); Toulouse, France (men); Catalonia, Spain (men)) and, on average, the prevalence of obesity was about 15% in men and 22% in women. Overweight, on the other hand, is much more common among men than among women. More than half

Table 4 Prevalence of overweight (BMI 25–30 kg/m²) and obesity (BMI ⩾ 30 kg/m²) in European women aged 35–64 years. Data from the WHO MONICA (first round 1983–1986) populations[16]

		Prevalence		
Country	Center	Overweight	Obese	Overweight+obese
Iceland	Iceland	30	11	41
Sweden	Northern Sweden	33	14	47
Sweden	Gothenburg	25	9	34
Finland	Kuopio Province	39	20	59
Finland	North Karelia	37	23	60
Finland	Turku–Loima	37	17	54
Denmark	Glostrup	25	10	35
UK	Glasgow	38	16	54
UK	Belfast	34	14	48
Germany	Bremen	37	18	55
Germany	Rhein-Neckar	31	12	43
Germany	Augsburg (urban)	36	15	51
Germany	Augsburg (rural)	36	22	58
Germany*	Halle County	36	25	61
Germany*	Karl-Marx-Stadt	31	19	50
Germany*	Cottbus County	36	23	59
Germany*	'Rest of DDR MONICA'	35	27	62
Belgium	Ghent	37	15	52
Belgium	Charleroi	35	26	61
Belgium	Luxembourg Province	33	18	51
France	Lille	30	18	48
France	Bas Rhin/Strassbourg	34	23	57
France	Haute Garonne/Toulouse	25	11	36
Switzerland	Vaud–Fribourg	30	12	42
Switzerland	Ticino	29	14	43
Russia	Novosibirsk (2 samples)	38	44	82
Russia	Moscow (2 samples)	39	34	73
Lithuania	Kaunas	38	45	83
Poland	Warsaw	39	26	65
Poland	Tarnobrzeg Voivodship	36	32	68
Czech Rep.	'Czechoslovakia'	37	31	68
Hungary	Pecs	34	26	60
Hungary	Budapest	36	18	54
Serbia	Novi Sad	40	30	70
Spain	Catalonia	44	24	68
Italy	Area Brianza	28	15	43
Italy	Friuli	37	19	56
Italy	Area Latina	43	30	73
Malta	Malta	32	41	73
95% CI of mean		33.2–36.0	18.8–24 6	52.5–60.1
Mean ± SD		34.6 ± 4.5	21.7 ± 9.1	56.3 ± 12.2

of the people aged 35–65 years in Europe seem to be either overweight or obese. Given the large within and between-country estimates of the prevalence of obesity, it is difficult to derive an overall prevalence figure for Europe as a whole from these data. It is fairly safe to assume that

such an overall prevalence figure would be in the range of 10–20% in men and 15–25% in women.

The study of explanations for the large diversity in prevalence data could give important clues to the understanding of the origins of common obesity. For example, the very high prevalence of obesity and mean body mass indexes in women from Eastern European countries is striking. There is only a moderate association (r=0.39, P=0.02) of the prevalence of obesity between men and women[17]. The distributions of the BMI values in men seem to be rather homogeneous over Europe, despite large socio-economic and cultural differences between the countries. In addition, it is clear that there are major differences in the mortality rates of cardiovascular disease which, at least in men, cannot be explained by differences in body mass index[17].

Table 5 Recent trends in obesity prevalence in some European countries and the US

Country	Obesity definition (BMI cut-off point)	Year	Ages	Men %	Women %
England	30 kg/m^2	1980	16–64	6	8
		1986/7		7	12
		1991		13	15
		1993		13	16
Sweden	Men: 30 kg/m^2	1980/1	16–84	4.9	8.7
	Women: 28.6 kg/m^2	1988/9		5.3	9.1
Finland	30 kg/m^2	1978/9	20–75	10	10
		1985/7		12	10
		1991/3		14	11
Germany	30 kg/m^2	1985	25–69	15.1	16.5
		1988		14.7	17.2
		1990		17.2	19.3
East Germany	30 kg/m^2	1985	25–65	13.7	22.2
		1989		13.4	20.6
		1992		20.5	26.8
The Netherlands	30 kg/m^2	1987	20–59	6.0	8.5
		1988		6.3	7.6
		1989		6.2	7.4
		1990		7.4	9.0
		1991		7.5	8.8
		1992		7.5	9.3
		1993		7.1	9.1
		1994		8.8	9.4
		1995		8.4	8.3
US	30 kg/m^2	1960/2	20–74	10.0	15.0
		1971/4		11.6	16.1
		1976/80		12.0	14.8
		1988/94		19.7	24.7

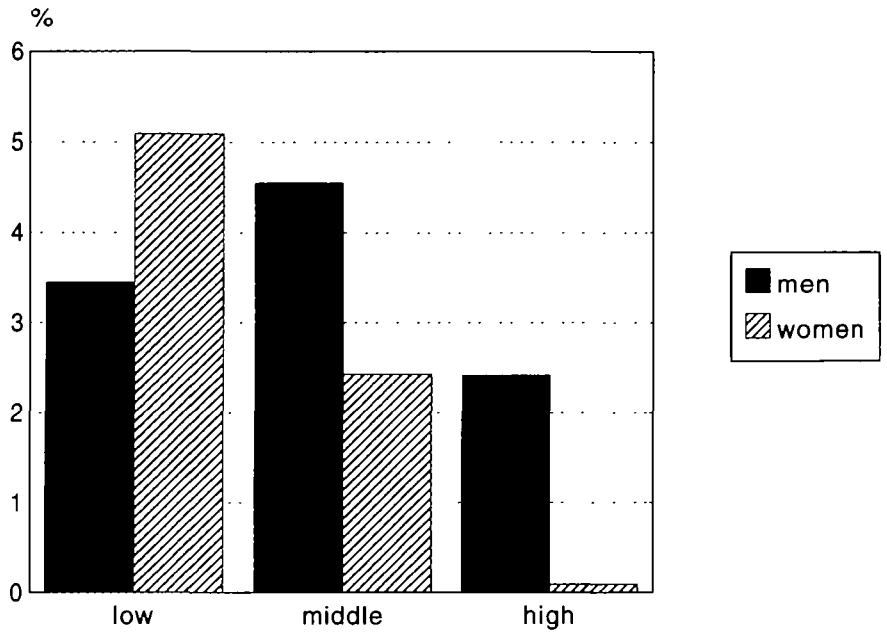

Fig. 4 Changes in prevalence of obesity (in percent over the period 1987–1995) in three Dutch towns by educational level (previously unpublished data). Low=primary education and lower vocational training; middle = secondary education and higher vocational training; high=tertiary education.

Trends in obesity prevalence in Europe and the US

Table 5 shows some of the available recent trend data on obesity in Europe and the US. The prevalence has increased by about 10–40% in most countries in the past decade. It escalated in the UK, where the prevalence has doubled during this period.

It seems that, in most countries, obesity is increasing in prevalence, although preliminary data from Denmark[18] show that in the period 1960–1980, the prevalence increased in men and decreased in women.

Subgroup analyses by sex, age and educational level with regard to time-trends yield different results in different countries. In some studies, the increase in the prevalence of obesity is most pronounced in young adults, whereas in others it is more pronounced in older subjects. Usually, there is a greater increase in the prevalence of obesity in those with relatively low educational levels compared to those with higher education. Figure 4 illustrates, with data from The Netherlands, that changes in body mass index may differ according to level of education.

National surveys in the US have shown a marked increase in the prevalence of obesity over time. During 1960–1980, there was only a slight increase in overweight. However, between 1980 and 1994 a striking increase in the prevalence of overweight occurred. This increase

was seen for all age groups, for both men and women, and for non-Hispanic whites, non-Hispanic blacks and Mexican-Americans. The magnitude of the increase was similar for all these groups. The US experience shows that a population-wide increase in the prevalence of overweight may occur relatively quickly after a long period during which the prevalence of overweight is fairly stable.

Causes of time trends in obesity

Diminished physical activity, high fat diets and inadequate adjustments of energy intakes to the diminished energy requirements are likely to be major determinants of the observed changes. Prentice and Jebb[19] have proposed that, on a population level, limited physical activity may be more important than energy or fat consumption in explaining the time-trends of obesity in the UK. Their analysis was based on surrogate measures of physical activity (such as number of hours spent watching television) and household consumption survey data. Such data are open to bias. Energy and fat consumption are selectively under-reported with increasing degrees of overweight[13]. Changes in smoking behaviour may also contribute to changes in body weight on a population level. Data from the US show that, although smoking cessation could explain some of the increase in the prevalence of overweight, smoking cessation alone could not account for the major portion of the increase[20]. In other studies it was also shown that the increase in obesity prevalence may be independent of smoking status[21,22].

Epidemiological methods that can be used to assess energy intake and energy expenditure not only may be subject to bias, but also have a high ratio of within to between-subject variation. It should be noted that only small changes in energy balance are needed to increase average BMI by one unit and, depending on the distribution of BMI in the population, could greatly increase the prevalence of obesity. Such small changes in energy balance may not be detectable by epidemiological measures of energy expenditure and intake.

It was previously shown[23] that dramatic increases in the prevalence of obesity in The Netherlands (about 37% in men and 18% in women over a period of 10 years) can be the consequence of relatively minor changes in average body weight. If height had remained constant, an average weight increase of only slightly less than 1 kg over 10 years could account for the increased prevalence of obesity observed. Such a small increase could reflect a minute change in energy balance on a daily basis. Experimentally, overfeeding with about 7,000 kcal will result in a weight gain of, on average, about 1 kg. If we neglect all metabolic

adaptations to overfeeding and increases in body weight, we can calculate that a constant positive energy balance of about 2 kcal/day may be sufficient to increase the average body weight of individuals by about 1 kg in 10 years and thus result in a substantial increase in the prevalence of obesity. It is clear that such small persistent changes in energy balance are not detectable by existing methods for measuring energy expenditure and energy intake in populations.

In The Netherlands, data from two identical nutrition surveys performed in 1987–1988 and 1993 suggested that energy intake decreased from 2329 kcal/day (9746 kJ) in 1987–1988 to 2216 kcal/day (9278 kJ) in 1993[24]. This reduction of about 113 kcal/day was attributable to a decrease in fat consumption (protein intake increased and carbohydrate and alcohol consumption remained constant). Smoking behaviour had changed, particularly in men, since the 1970s, but in the 1980s no further decrease was observed. This may imply that daily energy expenditure has decreased during the same period with the same order of magnitude. It is not uncommon in societies which are in a phase of 'post-modernisation' to see simultaneous improvement in dietary intakes (reduction in fat and energy) and increases in the prevalence of obesity[13].

Conclusions

Overweight and obesity are common in Europe and the US and, in most countries where reliable data are available, the prevalence seems to be increasing. Targets to reduce the prevalence of obesity to acceptable levels will not be reached in most countries[25,26]. International guidelines for the treatment and, in particular, the prevention of obesity are urgently needed[27]. They should be aimed at groups at high risk for weight gain. These include those who have a genetic predisposition for weight gain and obesity, but also those who change their life style (e.g. those who stop smoking or those who reduce their physical activity) and, perhaps, women who become pregnant. Special targets should be developed to reach specific socio-economic and ethnic groups which have a high prevalence of obesity. Efforts to prevent excessive weight gain in children and adolescents should be balanced against the possibility of inducing unnecessary dieting behaviour and eating disorders in girls.

Promoting physical activity is a priority in this context and attention should not just be focused on more participation in sports clubs but should also stimulate normal outdoor activities, such as walking and cycling and discouragement of 'sedentary behaviour'. International

guidelines, such as those prepared by the International Task Force on Obesity[27], can only be implemented when sufficient input and commitment of governments and health professionals have been obtained.

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