

ORIGINAL COMMUNICATION

A simple estimate of mortality attributable to excess weight in the European Union

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Objective: To estimate the current burden of mortality attributable to excess weight in the European Union (EU).

Methods: Prevalence of overweight (body mass index, BMI 25–29.9 kg/m²) and obesity (BMI ≥30 kg/m²) were based on self-reported data from a survey with samples representative of the 15 EU Member States in 1997. Primary source of relative risk (RR) of death by BMI was the first American Cancer Prevention Study (CPS I). Additional calculations were performed to account for effect of smoking (using CPS I data for non- or never-smokers), for pre-existing illness (using the second CPS, CPS II, data for healthy never-smokers) and using RRs derived from European rather than US data (using data from a meta-analysis of prospective studies). Mortality attributable to excess weight was calculated by combining the prevalences of overweight and obesity, the RRs, and the number of deaths in the EU countries.

Results: Annual deaths attributable to overweight and obesity totalled approximately 279 000 when RRs for all subjects were used. When RRs for nonsmokers only were applied to the entire population, about 304 000 deaths were attributable to excess weight. In analyses using RRs which controlled for both smoking and history of disease, the number of deaths attributable to excess weight was estimated at about 337 000 based on European data and at about 401 000 based on US data. In the EU, therefore, a minimum of 279 000 deaths were attributable to excess weight (7.7% of all deaths, varying from 5.8% for France through 8.7% for the UK). More attributable deaths occurred among the obese (175 000) than among the overweight (104 000). Around 70% were cardiovascular disease deaths (195 000) and 20% cancer deaths (53 000).

Conclusion: Mortality attributable to excess weight is a major public health problem in the EU. At least one in 13 annual deaths in the EU are likely to be related to excess weight.

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Introduction

Overweight and obesity are a common condition and their prevalences are rapidly increasing in Europe and around the world (Seidell, 1995a; World Health Organization,

2000). Moreover, there is growing evidence that excess weight is causally related to chronic diseases and all-cause mortality (World Health Organization, 2000; Manson *et al*, 1987; Troiano *et al*, 1996; National Institutes of Health, 1998).

Recent estimates for the USA put total deaths attributable to obesity and overweight at 280 000 in 1991 (Allison *et al*, 1999). Such information is important to any public health strategy aimed at reducing the burden of mortality attributable to this potentially avoidable cause (World Health Organization, 2000; National Institutes of Health, 1998). However, this information is not yet available for the countries in the European Union.

This study therefore sought to estimate the current burden of mortality attributable to overweight or obesity in the EU.

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Methods

For study purposes, we considered all-cause, cardiovascular disease and cancer mortality. The burden of mortality attributable to excess weight was calculated, as explained below, by combining the prevalences of overweight and obesity, the relative risks of death by body mass index (BMI, weight (kg) divided by height (m)²), and the number of deaths in the EU.

The number of deaths by sex and age (≥ 25 y) in the countries of the EU was drawn from the most recently available official vital statistics (Anonymous, 1996, 1998).

Subjects with a BMI ≥ 30 kg/m² were defined as obese (World Health Organization, 2000; National Institutes of Health, 1998), and those with BMI 25–29.9 kg/m² as overweight (National Institutes of Health, 1998; Seidell & Flegal, 1997) or pre-obese (World Health Organization, 2000; Seidell & Flegal, 1997). A BMI ≥ 25 kg/m² was deemed excess weight.

Primary data source for overweight and obesity prevalence was Pan-EU survey, a study based on self-reported weight and height (Institute of European Food Studies, Trinity College, Dublin, 1999). Additional calculations were performed using measured data taken from MONICA, CINDI and other studies to account for possible effect of self-reported data (World Health Organization MONICA Project, 1989; Morgenstern *W et al*, 1991; World Health Organization, 2000; Bergström *et al*, 2001; Table 1).

The Pan-EU is a cross-sectional study carried out in 1997, in which quota-controlled nationally representative samples of approximately 1000 subjects ≥ 15 y (overall, 15 239 subjects) were selected from each Member State, and where subjects reported their own height and weight. In each Member State, quota were defined by age, sex, region and

some social factors based on official statistics. We used data for the combined EU sample weighted for population size (the weighting factors being based on the population aged ≥ 15 y in each EU Member State) to ensure that those Member States with a small population size were not given undue emphasis in the context of the total EU, and for the individual countries (Institute of European Food Studies, Trinity College, Dublin, 1999; Kearney *et al*, 1997). The EU measurement-based data were used as compiled by Bergström *et al* (2001), corresponding to subjects aged 25–64 y, mostly studied in the mid-1980s. Their sources were heterogeneous and not necessarily representative of the whole host countries.

Primary source of relative risk (RR) data was the first American Cancer Society's Cancer Prevention Study (CPS I) for total mortality (Allison *et al*, 1999) and the study by Lew and Garfinkel (1979) for cancer and cardiovascular mortality (Table 2). Additional calculations were performed to account for the effect of smoking (using CPS I data for non- or never-smokers; Allison *et al*, 1999), for pre-existing illness (using the second CPS, CPS II, data for healthy never-smokers; Calle *et al*, 1999) and using RRs derived from European rather than US data (using data from a recent meta-analysis; Troiano *et al*, 1996; Table 2).

The CPS I and II constitute the largest cohorts in the world on the BMI–mortality relationship, and registered mortality among 1.2 million men and women in the US over a 12–14 y period (1960–1972 in CPS I, and 1982–1996 in CPS II; Allison *et al*, 1999; Lew & Garfinkel, 1979; Stevens *et al*, 1998; Calle *et al*, 1999). The sample was made up predominantly of white, middle-class subjects >30 y. We used RRs for all

Table 1 Prevalence of overweight and obesity in the European Union, by two data sources and country

Country	Pan-EU ^a		Measurement-based sources ^b			
	Overweight ^c	Obesity ^d	Men		Women	
			Overweight ^c	Obesity ^d	Overweight ^c	Obesity ^d
Austria	32	10	48	12	29	17
Belgium	31	9	49	15	36	20
Denmark	31	8	44	11	25	10
Finland	33	10	50	18	38	20
France	24	7	49	12	30	17
Germany	35	11	53	17	35	20
Greece	35	11	50	13	40	22
Ireland	31	8	47	11	32	17
Italy	30	7	48	15	36	21
Luxembourg	27	9	45	14	33	18
The Netherlands	29	10	45	11	31	11
Portugal	33	9	45	14	39	21
Spain	33	11	57	9	44	24
Sweden	33	7	45	10	29	12
UK	30	12	46	11	36	15
EU	31	10	50	13	35	19

^aSelf-reported data from a European Union survey (Institute of European Food Studies, Trinity College, Dublin, 1999).

^bMeasured data from MONICA, CINDI and other studies as compiled by Bergström *et al* (2001).

^cBMI 25–29.9 kg/m².

^dBMI ≥ 30 kg/m².

Table 2 Relative risk of overweight- and obesity-related mortality, by disease and study population

Study population	All-cause		Cardiovascular disease		Cancer	
	Overweight ^e	Obesity ^f	Overweight ^e	Obesity ^f	Overweight ^e	Obesity ^f
All subjects ^a	1.10	1.54	1.22	1.73	1.10	1.31
Non- or never-smokers ^b	1.12	1.56				
Healthy never-smokers ^c	1.17	1.74	1.25	2.05	1.11	1.43
European healthy nonsmokers ^d	1.09	1.77				

^aBased on Cancer Prevention Study I (Allison *et al*, 1999; Lew & Garfinkel, 1979).

^bBased on Cancer Prevention Study I (Allison *et al*, 1999).

^cBased on Cancer Prevention Study II (Calle *et al*, 1999).

^dBased on meta-analysis by Troiano *et al* (1996).

^eBMI 25–29.9 kg/m².

^fBMI ≥30 kg/m².

subjects controlled for age, sex and smoking status, and for only never-smokers with no history of disease. The reference category used was a BMI range of 23–25 kg/m². Where RRs were published by BMI units, we used the midpoint of the ranges studied (overweight and obesity; Allison *et al*, 1999; Lew & Garfinkel, 1979; Calle *et al*, 1999). Since the Lew and Garfinkel (1979) study used weight index categories, they were converted to approximately corresponding BMI units (Keys, 1980; Stevens *et al*, 1998). Lastly, we considered a meta-analysis of 17 prospective studies (half from the US and half from Europe), covering approximately 600 000 white men and women, middle-aged at entry, over a 10–30 y follow-up period (1960s–1980s; Troiano *et al*, 1996). In this study, the association between BMI and mortality was independent of smoking and concurrent illness. We used the meta-analysis-based RRs taken from predicted relationship between BMI and all-cause mortality for European white men, 50 y old at entry. These RRs were assumed to be equally applicable to females. However, this meta-analysis relied upon a lower sample size than the CPS, reported outcomes based on cumulative incidence rather than incidence rates (person-y), had limited information available for women, and indicated risk solely for all-cause mortality.

The population fractions attributable to overweight and obesity (PAF) were calculated using the following formula: $PAF_i = P_i (RR_i - 1) / (1 + \sum_i P_i (RR_i - 1))$ (Kleinbaum *et al*, 1982), where P_i is the proportion of the study population in the i th BMI category (overweight or obesity), and RR_i is the corresponding relative risk of death (the risk for the i th BMI category compared with the reference category 23–25 kg/m²). The symbol \sum_i refers to the sum of the products of each P_i times each $(RR_i - 1)$. The PAF for excess weight as a whole, was calculated by the formula: $PAF = (\sum_i P_i (RR_i - 1)) / (1 + \sum_i P_i (RR_i - 1))$ (Kleinbaum *et al*, 1982). PAF_{*i*} were calculated for the individual countries and the whole EU, and for all-cause, cardiovascular and cancer mortality. Finally, the resulting PAFs were then multiplied by the deaths in the EU Member States to obtain the number of deaths attributable to overweight, obesity and excess weight.

Results

The number of annual deaths attributable to excess weight among EU adults was approximately 279 000 based on self-reported prevalence data from the Pan-EU and RRs for all subjects (Table 3). The number of attributable deaths was 304 000 when RRs solely for non- or never-smokers were used (Table 3). In additional analyses with RRs that controlled for both smoking and history of disease, the number of deaths attributable to excess weight was estimated at about 337 000 based on European RR data and at about 401 000 based on US RR data (Table 3). Around 60–70% of all-cause attributable deaths were cardiovascular disease deaths and almost 20% were cancer deaths (Table 3).

When excess-weight prevalence was based on measured as opposed to self-reported weight and height, analyses yielded about 412 000–578 000 attributable deaths (Table 3). These figures are merely presented by way of illustration of the higher figures that can be expected if measured data are used instead of self-reported data (see 'Discussion'). The ranking of the number of attributable deaths among CPS I, CPS II and the meta-analysis was in accordance with their respective RR sizes (Table 3).

At least 279 000 annual deaths in the EU were attributable to overweight and obesity in the mid-1990s. This represents 7.7% of all deaths registered among adults ≥25 y. At least one in 13 annual deaths in the EU were therefore likely to be related to overweight or obesity. The highest numbers of attributable deaths were observed for Germany, the UK and Italy, and the lowest for Luxembourg, Ireland and Finland (data not shown), in line with population size. The attributable proportion varied from 5.8% for France to 8.7% for the UK (Figure 1). Although Finland registered one of the highest attributable proportions due to its high prevalence of excess weight, it nevertheless had a low number of deaths due to its low population size. France, in contrast, ranked last in terms of attributable proportion due to a relatively low prevalence of excess weight, but ranked among the highest in burden of absolute deaths due to its large population size.

Table 3 Proportion and number of deaths attributable to overweight and obesity in the European Union, by disease, data source for excess weight prevalence, and study population for relative risks

	All-cause-attributable deaths		Cardiovascular-attributable deaths		Cancer-attributable deaths	
	%	n	%	n	%	n
<i>Prevalence data from self-report-based source (Pan-EU)</i>						
RR for all subjects ^a	7.7	279 000	12.3	195 000	5.7	53 000
RR for non- or never-smokers ^b	8.3	304 000				
RR for healthy never-smokers ^c	11.0	401 000	15.3	242 000	7.0	64 000
RR for European healthy nonsmokers ^d	9.2	337 000				
<i>Prevalence data from measurement-based sources</i>						
RR for all subjects ^a	11.3	412 000	17.3	275 000	8.3	77 000
RR for non- or never-smokers ^b	12.2	445 000				
RR for healthy never-smokers ^c	15.9	578 000	21.5	341 000	10.2	94 000
RR for European healthy nonsmokers ^d	13.8	501 000				

Attributable fractions (%) were calculated by applying excess weight prevalence data from the Pan-EU (Institute of European Food Studies, Trinity College, Dublin, 1999) or from measurement-based sources (Bergström *et al*, 2001) to relative risks (RR) of death from several data sets. All numbers of attributable deaths were rounded to the nearest 100.

^aBased on Cancer Prevention Study I (Allison *et al*, 1999; Lew & Garfinkel, 1979).

^bBased on Cancer Prevention Study I (Allison *et al*, 1999).

^cBased on Cancer Prevention Study II (Calle *et al*, 1999).

^dBased on meta-analysis by Troiano *et al* (1996).

More attributable deaths occurred among obese (175 000, or 4.8% of all deaths) than among overweight subjects (104 000, or 2.9% of all deaths), reflecting the higher RR associated with obesity. A total of 195 000 cardiovascular deaths (12.3% of total cardiovascular deaths) and 53 000 cancer deaths (5.7% of total cancer deaths) were attributable to overweight or obesity.

Discussion

A minimum of approximately 279 000 annual deaths were attributable to excess weight in the EU, about two-thirds deriving from obesity and one-third from overweight. One in two subjects in the EU is obese or overweight, and at least one in 13 deaths were obesity- or overweight-related. In the EU, excess weight therefore represents a remarkable burden of potentially avoidable deaths. As will be discussed below, these estimates are approximate and potentially conservative.

Tobacco smoking is the leading avoidable cause of death in many developed countries (Murray & Lopez, 1996). Indeed, smoking caused about 510 000 deaths (about 15% of all deaths) in the adult population of the EU in 1995 (Peto *et al*, 1994). Excess weight, however, affecting approximately half the population, would also appear to rank among the top causes of death. For illustrative purposes, the relative contribution of excess weight and tobacco smoking to deaths from all causes in the EU is shown in Figure 1. Moreover, as prevalence of smoking is decreasing whereas that of excess weight is increasing over time, excess weight

may well come to replace smoking as the major killer of adults in the near future. Yet, unlike the stance adopted towards tobacco, for which control policies have been implemented in many countries, most countries have not yet made any systematic effort to raise public awareness as to the dangers of obesity (Grundy, 1998). Excess weight should be given higher priority on the public health agenda. As to other major risk factors for death, physical inactivity also seems to account for an important part of total death burden. The Global Burden of Disease Study (Murray & Lopez, 1996) estimated that in countries with established market economies, the percentage of deaths attributed to physical inactivity was 11.7%. As to the EU, since the prevalence of physical inactivity during leisure time (as reported by Pan-EU); (Institute of European Food Studies, Trinity college, Dublin, 1999) was lower than that of excess weight (32 vs 41%), and since RRs for sedentariness-related diseases are usually <2 (Brownson *et al*, 1993), the attributable fraction is likely to be lower for physical inactivity than for excess weight. Finally, in terms of disability-adjusted life years (DALYs), the National Institute of Public Health in Stockholm estimated that 1.4% of DALYs lost in the EU are due to physical inactivity, 4% to excess weight, 5% to diets high in saturated fat and low in fruit and vegetables, and 9% to smoking (National Institute of Public Health, Stockholm, 1997).

Using prevalences based on measured weight and height, and RRs for all subjects from the CPS I, Allison *et al*, (1999), estimated that in the USA there were approximately 244 000 deaths attributable to overweight and obesity in 1991. This

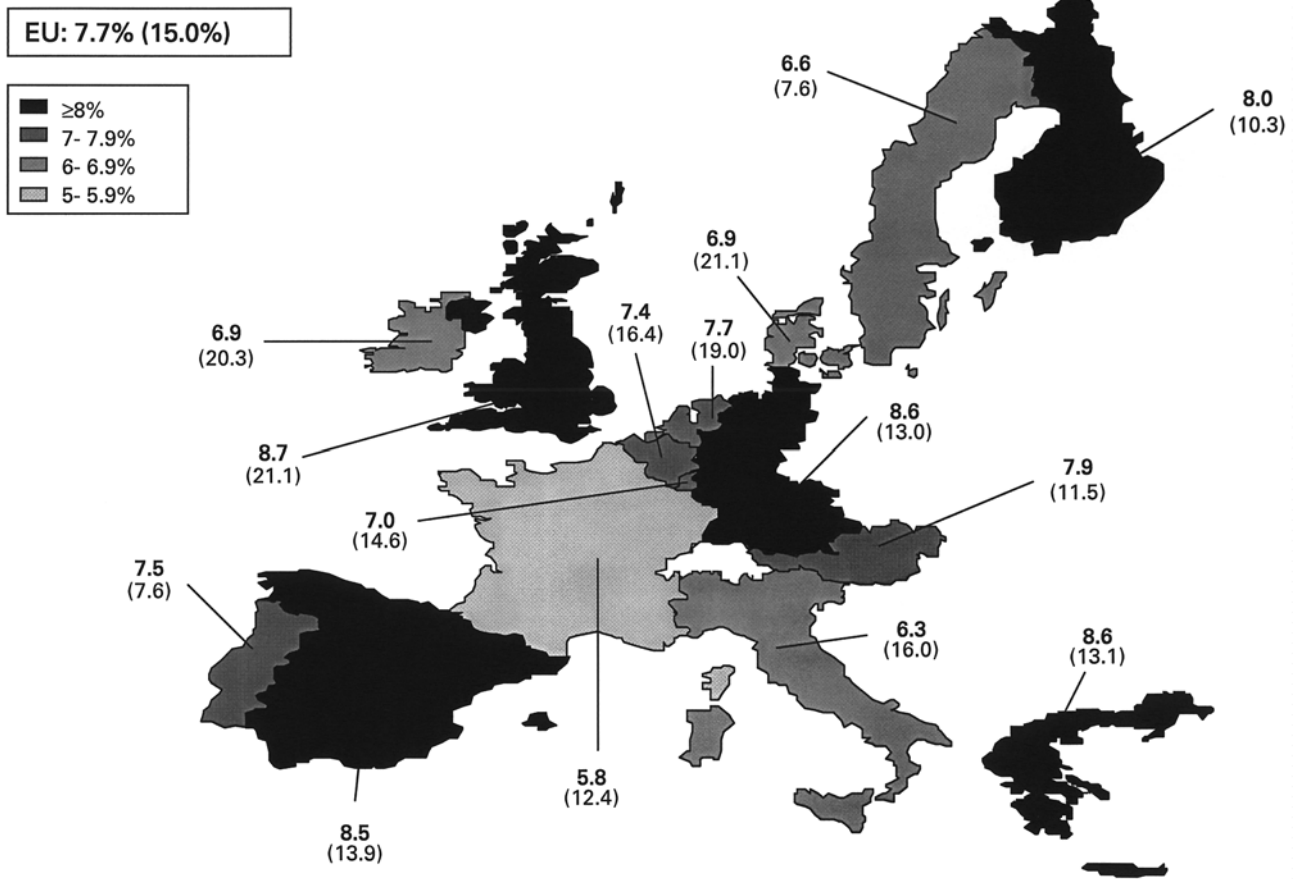


Figure 1 Proportion of all-cause deaths attributable to excess weight and to smoking (the latter in parentheses) in EU countries. Black and white gradation of countries in the map corresponds to their proportion of deaths due to excess weight. Calculations of deaths attributable to excess weight were based on prevalence data from the Pan-EU (Institute of European Studies, Trinity College, Dublin, 1999) and relative risks from CPS I (Allison *et al*, 1999). Deaths due to smoking were taken from Peto *et al* (1994).

represented about 12% of all US deaths. The equivalent EU figure was roughly in the region of 412 000 deaths (11% of all deaths) for the period in and around the mid-1990s (Table 3). The higher number of attributable deaths in the EU is due the population size being higher than that of the USA. The slightly lower attributable fraction in the EU is partly due to its lower prevalence of obesity. Bergström *et al*, on the other hand, estimated that there were over 70 000 cases of cancer attributable to excess weight in the EU in 1995, using measured weight and height, and studying cancer of the breast, colon, endometrium, prostate, kidney and gallbladder (Bergström *et al*, 2001). Using the same prevalence data, we arrived at an estimate of 77 000 all-cancer deaths related to excess weight in the EU in 1995.

This study is subject to some limitations, relating to RR data and data on the prevalence of excess weight. Firstly, RRs decrease as age advances (Stevens *et al*, 1998), at a stage when most deaths occur in the population (Anonymous, 1996, 1998). Since non-age-specific RRs were used, this may have

led us to overestimate attributable deaths to some degree. Nevertheless, the prevalence of excess weight tends to increase or stabilize at higher levels with age (Institute of European Food Studies, Trinity College, Dublin, 1999). Specifically, the prevalence of obesity for the general population from Pan-EU is about 1–2% lower than that in older ages. Since prevalence data for the general population were used, it may have thus partly offset the previous effect of RRs. At all events, as in other studies (Allison *et al*, 1999), our interest lay in estimating the average effect of excess weight across all adult ages and for both sexes.

Secondly, RR data was not available for all EU countries. However, despite the fact that RRs can change from one population to another, the major determinant of variation (as between different populations) in the attributable burden due to a particular risk factor is not usually differences in RR, but rather differences in the population distribution of exposure levels (Murray & Lopez, 1996). This assertion is valid at least for those exposures, such as excess weight, for

which the RR does not change dramatically over time (Troiano *et al*, 1996; Allison *et al*, 1999; Lew & Garfinkel, 1979; Calle *et al*, 1999; Murray & Lopez, 1996). Furthermore, such RRs are fairly similar throughout the world (World Health Organization, 2000), and if properly standardized, can be transferred from one population to another (Gunning Schepers, 1989; Walter, 1978). Thus, as other studies did (Bergström *et al*, 2001; Murray & Lopez, 1996; Gunning Schepers, 1989), we used reasonable RR estimates, taking their internal validity and generalizability into account (see next paragraph), and performed several additional analyses, which, using RRs from different settings and countries, yielded a range of expected variation in results. To this end, we used RRs from the meta-analysis considered (Troiano *et al*, 1996), and the corresponding analysis gave a range of expected variation in results when European (Troiano *et al*, 1996), instead of US, RRs were used (Table 3). Nevertheless, this meta-analysis was not used for primary analysis owing to its limitations (see the Methods section). Furthermore, the Seven Countries study showed that, for all-cause deaths, southern European men differed only slightly from their American and northern European counterparts in the strength of the risk factors (including BMI; Keys *et al*, 1984), and, specifically, among European obese male ex- or never-smokers (Visscher *et al*, 2000), the RR for all-cause mortality was very close to the estimates we used. In addition, RRs were similar for different regions of Europe (Visscher *et al*, 2000). These facts lend some support to our assumption, likewise made by other studies (Bergström *et al*, 2001), that RRs would be the similar among the EU countries. This is also supported by the fact that variation in death rates among EU countries is quite small (the top age-standardized death rate, found in Finland, is only 1.2 times the lowest rate, found in France; Anonymous, 1996, 1998).

Thirdly, while analysis using RRs for all subjects adjusted only for smoking, sex and age may be more applicable to the total population comprising both smokers and nonsmokers, it may nonetheless furnish potentially conservative estimates of the number of deaths attributable to excess weight (279 000). These RRs are not adjusted for potential confounding from prevalent chronic disease at baseline or for residual confounding from smoking (amount or way of smoking), both of which are associated with lower body weight and increased mortality (Manson *et al*, 1987). When CPS I-based RRs solely for non- or never-smokers were applied to the entire population, only about 8% more deaths were attributable to excess weight (Table 3). In analyses using RRs that controlled for or excluded smoking and history of disease (using the meta-analysis or CPS II data), the number of deaths attributable to excess weight was estimated at 337 000 and 401 000, respectively (Table 3), ie figures that were 20–40% higher. This may be due to RRs of death related to excess weight being about 0.1–0.2 points lower for the whole population than when controlling for smoking and pre-existing illness (see Table 2). How-

ever, uncontrolled confounding by other factors (such as early disease (Mikkelsen *et al*, 1999), recent unintentional weight loss (Stevens *et al*, 1998), long-term weight loss (Calle *et al*, 1999), weight level (Mikkelsen *et al*, 1999), etc) may still be present, meaning that estimation of the true adverse effect of excess weight might be biased to a certain extent.

Moreover, aside from any possible confounding, effect modification by covariates might also be in evidence (Seidell, 1995b). In this respect, however, the literature is divided as to whether residual confounding or effect modification by smoking (or pre-existing illness or weight fluctuation) is likely (World Health Organization, 2000; Manson *et al*, 1987; Troiano *et al*, 1996; National Institutes of Health, 1998; Allison *et al*, 1999; Lew & Garfinkel, 1979; Stevens *et al*, 1998; Calle *et al*, 1999; Sempos *et al*, 1998). Thus, in line with other studies (Allison *et al*, 1999), we estimated attributable deaths separately, using RRs for all subjects and using RRs for non- or never-smokers (and additionally for apparently healthy subjects). Whereas the former RRs afford the best estimates in cases where no residual confounding exists after statistical control, the latter afford the best estimates in cases where there is no effect modification; and in those cases where both residual confounding and effect modification exist, the best estimates may lie between these two estimates (Allison *et al*, 1999). Overall, one can therefore conclude that the likely impact of excess weight in the EU may, depending on the assumptions about RRs, vary between 280 000 and 400 000 attributable deaths. In other words, a minimum of 280 000 deaths are in all likelihood attributable to excess weight in the EU.

Fourthly, although self-reported weight and height have a relatively high validity (Nieto-García *et al*, 1990), they underestimate the true prevalence of obesity, as compared with measured data (Stevens *et al*, 1990). Specifically, the prevalence of obesity was, in absolute terms, about 6% lower in Pan-EU than in measurement-based sources (see Table 1). Likewise prevalence of overweight was about 11% lower in Pan-EU. Attributable deaths may thus be underestimated (Table 3). However, measurement-based attributable deaths are quoted only as illustrative figures, since they were not based on weight and height representative of the EU countries.

Fifthly, rather than take induction periods into account, current prevalence of obesity was instead assumed to be a proxy for the cumulative effect of obesity over decades of life. Indeed, as the prevalence of obesity in different countries of the EU for which data on time trends are available has increased about 1–5% (except a higher increase in England) over recent decades (Seidell, 1995a; Institute of European Food Studies, Trinity College, Dublin, 1999), some overestimation in current attributable mortality may well have occurred. Finally, our calculations assumed that (controlling for age, sex, and smoking) all excess mortality among obese individuals was due to obesity.

Therefore, while the overall effect of the above limitations on our estimates of mortality attributable to excess weight is

not totally clear, it is likely that those limitations that tend to underestimate the impact of excess weight on health (limitations three and four) would not be completely offset by others that tended to overestimate such impact (limitation five in particular).

Given some uncertainty in input data, our figures for attributable deaths are approximate, pending further studies purpose-designed to furnish specific, more valid RR estimates and representative measurement-based prevalence of excess weight for each European country. At all events, our primary figures (279 000–304 000 deaths) are likely to be conservative estimates, owing to the limitations commented above. Indeed, given the above-mentioned uncertainty in input data, it is important to remain conservative when estimating attributable mortality, among other things, to avoid the danger of exaggerating estimates to make them more interesting for public health purposes (Murray & Lopez, 1996). Yet, despite the problems discussed here, an approximate quantification must nevertheless be attempted if epidemiology is to contribute effectively to the improvement of public health (Murray & Lopez, 1996), and to focus debate on appropriate policy responses to such a major cause of mortality burden as excess weight.

In the EU, excess weight has greatly increased in the last few decades (Seidell, 1995a; World Health Organization, 2000), and the population of most EU countries is progressively aging. Consequently, more and more excess-weight-related deaths may occur. National strategies involving a whole range of different departments (Seidell, 1995a; World Health Organization, 2000; James, 1995) are called for, to reduce the problem of excess weight in the EU. The public health impact of excess weight has been examined here in terms of mortality, yet it should also be measured by its combined effect on disability and mortality, as well as its impact on physical performance, quality of life and health costs (World Health Organization, 2000; James, 1995; Visscher & Seidell, 2001).

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