# Effect of Age on Excess Mortality in Obesity

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**Context** The effect of age on excess mortality from all causes associated with obesity is controversial. Few studies have investigated the association between body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), age, and mortality, with sufficient numbers of subjects at all levels of obesity.

**Objective** To assess the effect of age on the excess mortality associated with all degrees of obesity.

**Design** Prospective cohort study.

**Setting and Participants** A total of 6193 obese patients with mean (SD) BMI of 36.6 (6.1) kg/m$^2$ and mean (SD) age of 40.4 (12.9) years who had been referred to the obesity clinic of Heinrich-Heine University, Düsseldorf, Germany, between 1961 and 1994. Median follow-up time was 14.8 years.

**Main Outcome Measure** All-cause mortality through 1994 among 6053 patients for whom follow-up data were available (1028 deaths) analyzed as standardized mortality ratios (SMRs) using the male-female population of the geographic region (North Rhine Westphalia) as reference.

**Results** The cohort was grouped into approximate quartiles according to age (18-29, 30-39, 40-49, and 50-74 years) and BMI (25 to <32, 32 to <36, 36 to <40, and ≥40 kg/m$^2$) at baseline. The SMRs showed a significant excess mortality with an SMR for men of 1.67 (95% confidence interval, 1.51-1.85; $P<.001$) and an SMR for women of 1.45 (95% confidence interval, 1.34-1.57; $P<.001$). The excess mortality associated with obesity declined with age. For men, the SMRs of the 4 age groups were 2.46, 2.30, 1.99, and 1.31, respectively; for women, they were 1.81, 2.10, 1.70, and 1.26, respectively (Poisson trend test, $P<.001$). The SMRs increased with BMI but, within each BMI group, the SMRs decreased with age. The lowest SMRs (for men, 1.01; for women, 0.91) were obtained for patients older than 50 years with BMIs of 25 to less than 32 kg/m$^2$. Thus, older men and women at a BMI range of 25 to less than 32 kg/m$^2$ had no excess mortality. The highest SMRs (for men, 4.22; for women, 3.79) were calculated for the patients aged 18 to 29 years with a BMI of 40 kg/m$^2$ or higher.

**Conclusions** In this large cohort of obese persons, risk of death increased with body weight, but obesity-related excess mortality declined with age at all levels of obesity.

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The association between body weight and mortality remains controversial.[1] Although in general, a J- or U-shaped relationship is accepted, questions remain about the degree of excess mortality associated with obesity and the impact of age on the relationship between overweight and mortality.[1] Most studies about this issue have shown a decrease of the obesity-related excess risk with increasing age,[2-12] implicating a relatively high optimal body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters) of about 30 kg/m$^2$ associated with minimum mortality in older persons.[13] However, only a few studies have had sufficient size to describe in detail the dependence of mortality on body weight and age. Recently, Stevens et al[14] suggested that the relative risk (RR) associated with greater body weight declined with age in adults older than 30 years. The study cohort consisted of participants of the American Cancer Society's Cancer Prevention Study, with a BMI distribution similar to that of a normal population. The mean BMI was 25 kg/m$^2$ and the largest BMI category chosen was that of at least 32 kg/m$^2$. Hence, it was impossible to investigate the effect of age on the excess mortality associated with higher degrees of obesity. There are very few studies investigating the mortality of extremely obese subjects.[9]

In this article, the associations among body weight, age, and mortality are investigated by using the data of the Düsseldorf Obesity-Mortality Study (DOMS).[15] In this study, a large cohort of obese patients, including a considerable number of grossly obese (BMI, 32 to <40 kg/m$^2$) and morbidly obese (BMI, ≥40 kg/m$^2$) individuals, was recruited during a period of 33 years and followed up for a median of 14.8 years. The

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excess mortality associated with several degrees of obesity was assessed by means of a comparison of the study cohort with the general population living in the same geographic area.[15] Here, we present an analysis for different age groups to assess the effect of age on the excess mortality associated with several degrees of obesity.

## METHODS

### Subjects and Data

The DOMS is a prospective cohort study of 6193 obese patients (1591 men and 4602 women) who had been referred to the obesity clinic of Heinrich-Heine University, Düsseldorf, Germany, between 1961 and 1994. In general, the referral of overweight patients to the obesity clinic was made by their general practitioners to involve them in a 4184-J/d dietary treatment plan that included elements of group therapy and behavior modification.[16] Some patients were also referred by the endocrine clinic at Heinrich-Heine University or by surgical departments to achieve weight loss before elective surgery. All services of the obesity clinic were provided free of charge to the patient.

The initial medical examination included a history taking, physical examination, and clinical chemistry. The design and data collection have been described in detail previously.[15] In short, the following baseline data were collected at the initial medical examination: date of examination, name, current address, sex, date of birth, height, weight, blood pressure, glucose tolerance, and cholesterol level. In addition, since 1977, information on smoking habits has been collected systematically. Inclusion criteria were age at entry of 18 to 74 years and a BMI of at least 25 kg/m$^2$. Height and weight were measured with the patients in light clothes (shirts and trousers or skirts), without shoes. Blood pressure was measured by means of a mercury sphygmomanometer; serum cholesterol and blood glucose levels were measured by routine clinical chemistry methods, as described previously.[17]

Glucose tolerance was assessed by measuring the capillary blood glucose level 2 hours after a 100-g oral glucose load was given after an overnight fast. A patient was classified as having diabetes if the diagnosis of diabetes was previously known, if the fasting blood glucose level was at least 6.7 mmol/L (120 mg/dL), or if the glucose tolerance test yielded a capillary blood glucose level of at least 11.1 mmol/L (200 mg/dL). A patient was classified as having impaired glucose tolerance if the glucose tolerance test yielded 2-hour capillary blood glucose values of at least 7.8 mmol/L (140 mg/dL) and less than 11.1 mmol/L (200 mg/dL). After 1972, all patients signed an agreement that their data could be used in the context of scientific studies. The impact of blood pressure, cholesterol, glucose tolerance, and smoking on mortality was investigated previously.[15] In this article, we concentrate on the effect of age on the excess mortality associated with obesity.

### Mortality Follow-up

Vital status was ascertained from municipal residents' registries. Vital status up to 1994 could be determined for 5775 patients (93.3%). Additionally, the vital status of 278 patients up to any point earlier than 1994 was obtained from former follow-up investigations or removal dates. Thus, we could calculate patient-year data based on 6053 patients (97.7%). We could not obtain survival data for only 140 patients (2.3%). All available survival data were used as either event or censored observation. The patients' survival time was principally calculated on a daily basis.

### Statistical Analysis

To investigate the associations among weight, age, and mortality, we grouped the study population approximately into quartiles according to age at baseline (group 1, 18-29; group 2, 30-39; group 3, 40-49; and group 4, 50-74 years) and BMI (group 1, 25 to $<$32; group 2, 32 to $<$36; group 3, 36 to $<$40; and group 4, $\geq$40 kg/m$^2$). Body mass index of at least 25 but less than 32 kg/m$^2$ (group 1) was referred to as *moderate* obesity; BMI between 32 and less than 40 kg/m$^2$ (groups 2 and 3) was *gross* obesity; and BMI of 40 kg/m$^2$ or more (group 4) was *morbid* obesity.

We calculated standardized mortality ratios (SMRs)[18] separately for men and women within the 4 age groups and the 16 age-by-BMI groups by using the male and female populations of North Rhine Westphalia, Germany, as reference populations, respectively. The SMRs permit a comparison of the mortality of the obese study population with the mortality of a complete general population living in the same geographic area. The mortality ratios were standardized in an indirect manner[18] according to age and calendar year, using 1-year intervals. The population and mortality data of North Rhine Westphalia for age and calendar year were made available on a 1-year basis from the State Office for Data Processing and Statistics of North Rhine Westphalia, Düsseldorf. Significance tests and 95% confidence intervals for the SMRs were calculated by using the Byar approximation to the exact Poisson test and exact Poisson limits.[18] Whether there was a trend in the SMRs across age groups was investigated by means of the Poisson trend test.[18]

To quantify and compare the impact of sex, age, and BMI on the excess mortality associated with obesity, multiple linear regression was used. In this model, the estimated SMRs served as dependent variables and sex, mean age, and mean BMI of the corresponding age-by-BMI groups were used as explanatory factors. The risk factors systolic and diastolic blood pressure, cholesterol level, impaired glucose tolerance, diabetes, and smoking were also investigated. To take the heteroscedasticity of the SMRs into account, the weighted least squares method was applied, using the SEs of the SMRs as weights. It should be noted that such a simple model cannot be used to describe the relationship between excess mortality and the considered factors in detail. However, the estimated regression coefficients give a rough impression of the impact of sex, age, and BMI on the excess mortality, because they represent the average change in SMR associated with a change of 1 unit in the explanatory factors.

For computations, the SAS procedures UNIVARIATE,[19] MEANS,[19] FREQ,[20] and REG[20] were used. Standardized mortality ratios and corresponding *P* values and confidence intervals were calculated by means of programs written in matrix language using SAS/IML.[21]

## RESULTS

Patients were recruited between 1961 and 1994 and followed up for a median of 14.8 years (mean [SD], 14.3 [8.2]; range, 0-33; interquartile range, 7.3-20.2 years). The range for BMI was 25.0 to 74.4 kg/m² (mean [SD], 36.6 [6.1] kg/m²) and for age was 18 to 74 years (mean [SD], 40.4 [12.9] years). Up to 1994, 1028 patients (16.6%) died (365 men and 663 women). The total number of observed patient-years was 87 179 (for men, 21 932; for women, 65 247). The crude mortality rate was 11.79 deaths per 1000 patient-years (for men, 16.64; for women, 10.16). A descriptive analysis of the baseline data within the 4 age groups is shown in TABLE 1.

The estimated SMRs for men and women within age and age-by-BMI groups are shown in TABLE 2, TABLE 3, FIGURE 1, and FIGURE 2. Overall and within the BMI groups, the SMRs for both sexes tended to decrease with age. Due to the limited event numbers, especially in the lower age groups, the SMRs dependent on age and BMI show some irregularities. Overall, in women as well as in some BMI groups for men and women, the SMRs for the first age group were lower than for the second. However, the number of deaths in the first age group was very low, causing the confidence intervals to be wide. Hence, these results do not rule out a general decreasing trend in SMRs across age groups. Overall, the decreasing trend of SMRs across age groups was statistically significant in both sexes ($P<.001$). A substantial excess mortality (SMR >1.5) was observed for moderately obese men (BMI, 25 to <32 kg/m²) who were younger than 40 years, for men with a BMI of at least 32 but less than 36 kg/m² who were younger than 50 years, and for men with a BMI of 36 kg/m² or more. For women, SMRs higher than 1.5 were obtained only in morbidly obese patients (BMI ≥40 kg/m²) and those with a BMI of 36 to less than 40 kg/m² who were younger than 40 years. Assuming that the very low SMR of 0.84 in the group of women aged 18 to 29 years with a BMI of at least 36 but less than 40 kg/m² is due to random error, the lowest ex-

**Table 1.** Descriptive Analysis of Baseline Data Within Age Groups*

| Characteristics | Total (N = 6193) | Age Group, y: 18-29 (n = 1598) | 30-39 (n = 1432) | 40-49 (n = 1567) | 50-74 (n = 1596) |
|---|---|---|---|---|---|
| **Men** | | | | | |
| | (n = 1591) | (n = 444) | (n = 375) | (n = 385) | (n = 387) |
| Age, y | 39.7 (13.2) | 23.5 (3.5) | 35.0 (3.0) | 45.2 (2.9) | 57.4 (5.0) |
| BMI, kg/m² | 36.6 (5.9) | 37.1 (5.5) | 37.2 (6.9) | 36.7 (5.9) | 35.4 (5.0) |
| Weight, kg | 112.6 (20.3) | 116.9 (18.7) | 115.5 (23.7) | 112.1 (20.0) | 105.3 (16.2) |
| Height, cm | 175.3 (7.1) | 177.6 (7.2) | 176.0 (6.9) | 174.6 (6.9) | 172.6 (6.5) |
| SBP, mm Hg | 161.4 (26.9) | 160.7 (25.2) | 157.9 (26.0) | 162.5 (30.0) | 164.5 (26.1) |
| DBP, mm Hg | 100.8 (17.3) | 99.2 (16.0) | 101.4 (16.7) | 103.2 (19.8) | 99.7 (16.2) |
| Cholesterol level, mmol/L† | 6.21 (1.51) | 5.55 (1.21) | 6.26 (1.62) | 6.47 (1.49) | 6.44 (1.52) |
| Diabetes, No. (%) | 304 (21.6) | 14 (3.7) | 54 (16.50) | 83 (23.7) | 153 (44.3) |
| IGT, No. (%) | 217 (15.4) | 33 (8.6) | 43 (13.1) | 71 (20.3) | 70 (20.3) |
| Ever smoked, No. (%) | 341 (65.5) | 39 (41.1) | 68 (66.7) | 103 (68.7) | 131 (75.3) |
| **Women** | | | | | |
| | (n = 4602) | (n = 1154) | (n = 1057) | (n = 1182) | (n = 1209) |
| Age, y | 40.7 (12.8) | 24.3 (3.4) | 35.1 (2.9) | 44.9 (2.9) | 57.1 (5.2) |
| BMI, kg/m² | 36.6 (6.2) | 35.6 (5.9) | 36.8 (6.5) | 37.1 (6.5) | 36.9 (5.9) |
| Weight, kg | 97.2 (17.4) | 97.2 (17.2) | 98.6 (18.3) | 97.7 (17.9) | 95.0 (15.8) |
| Height, cm | 162.8 (6.7) | 165.2 (6.4) | 163.6 (6.2) | 162.4 (6.6) | 160.3 (6.5) |
| SBP, mm Hg | 158.4 (28.3) | 148.5 (23.4) | 153.5 (25.9) | 161.3 (29.6) | 169.4 (29.1) |
| DBP, mm Hg | 97.8 (15.9) | 92.6 (14.2) | 97.2 (15.8) | 99.7 (16.1) | 101.4 (16.0) |
| Cholesterol level, mmol/L† | 5.95 (1.29) | 5.37 (1.16) | 5.68 (1.10) | 6.03 (1.20) | 6.63 (1.33) |
| Diabetes, No. (%) | 602 (14.7) | 27 (2.6) | 89 (9.4) | 170 (16.1) | 316 (29.6) |
| IGT, No. (%) | 696 (16.9) | 124 (11.9) | 172 (18.2) | 194 (18.4) | 206 (19.3) |
| Ever smoked, No. (%) | 639 (36.8) | 171 (48.3) | 156 (40.9) | 174 (36.3) | 138 (26.5) |

*Data are expressed as mean (SD) unless otherwise noted. BMI indicates body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; and IGT, impaired glucose tolerance. BMI was missing for 12 patients, blood pressure for 260, glucose tolerance for 678, cholesterol level for 1724, and smoking for 3937.
†To convert millimoles per liter to milligrams per deciliter, divide by 0.02586.

cess mortality was found for moderately obese men (SMR, 1.01) and women (SMR, 0.91) who were aged 50 years or older. The highest excess mortality was observed for morbidly obese men (SMR, 4.22) and women (SMR, 3.79) who were younger than 30 years.

In the multiple linear regression analysis with the estimated SMRs as values of the dependent variable, sex ($\beta = .56$; $P = .02$), age ($\beta = -.03$; $P = .007$), and BMI ($\beta = .13$; $P < .001$) were, as expected, significantly associated with SMR. Because none of the possible interactions were significant, the model containing only main effects was used. With this simple model, it was not possible to show additional significant effects of the other risk factors (blood pressure, cholesterol level, impaired glucose tolerance, diabetes, and smoking) on the obesity-related excess mortality. However, the regression coefficients for age and BMI did not change significantly when one of the other risk factors was included in the model. The coefficient of determination for the model was $R^2 = 0.697$; ie, sex, age, and BMI explained about 70% of the variance of the SMRs. The inverses of the regression coefficients give the average change of units in the explanatory factors associated with a change of 1.0 in the SMRs (eg, from 1.5 to 2.5). Multiplying the inverses of the regression coefficients of age and BMI by the regression coefficient of sex yields the difference of 19.1 years for age and 4.3 kg/m² for BMI, which have the same effect on excess mortality as sex (ie, an SMR increase of 0.555).

## COMMENT

This study represents by far the largest mortality follow-up of a cohort of obese patients, including a considerable number of grossly obese (BMI of 32 to <40 kg/m²) and morbidly obese (BMI ≥40 kg/m²) subjects. We have compared the mortality rates of this cohort of obese patients with the general population of North Rhine Westphalia, Germany, stratified for sex, age, and BMI and standardized for age and cal-

**Table 2.** Standardized Mortality Ratios Within Age Groups*

| | Men | | | | | Women | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age Range, y | No. | No. of Deaths | SMR | 95% CI | *P* Value | No. | No. of Deaths | SMR | 95% CI | *P* Value |
| 18-29 | 444 | 36 | 2.46 | 1.72-3.41 | <.001 | 1154 | 31 | 1.81 | 1.23-2.57 | .003 |
| 30-39 | 375 | 63 | 2.30 | 1.77-2.95 | <.001 | 1057 | 85 | 2.10 | 1.68-2.60 | <.001 |
| 40-49 | 385 | 105 | 1.99 | 1.62-2.40 | <.001 | 1182 | 176 | 1.70 | 1.46-1.97 | <.001 |
| 50-74 | 387 | 161 | 1.31 | 1.11-1.52 | .001 | 1209 | 371 | 1.26 | 1.13-1.39 | <.001 |
| **Total** | **1591** | **365** | 1.67 | 1.51-1.85 | <.001 | **4602** | **663** | 1.45 | 1.34-1.57 | <.001 |

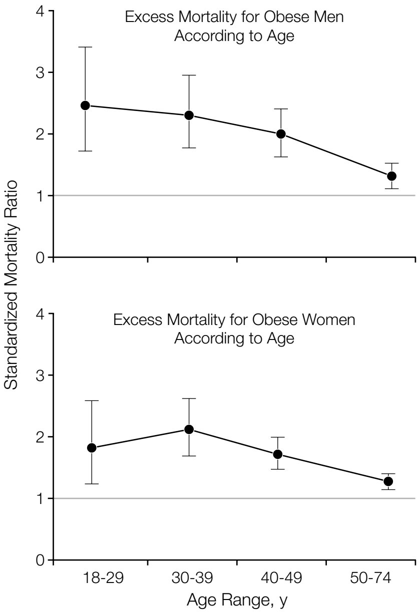
*Standardized mortality ratios (SMRs) were calculated by using the male and female populations of North Rhine Westphalia, Germany, as reference populations. A test for trend was significant (*P*<.001) for both sexes. CI indicates confidence interval.

**Table 3.** Standardized Mortality Ratios Within BMI and Age Groups*

| | | Men | | | | | Women | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BMI, kg/m² | Age Range, y | No. | No. of Deaths | SMR | 95% CI | *P* Value | No. | No. of Deaths | SMR | 95% CI | *P* Value |
| 25 to <32 | 18-29 | 70 | 5 | 1.93 | 0.62-4.51 | .24 | 339 | 5 | 1.09 | 0.35-2.53 | .97 |
| | 30-39 | 74 | 11 | 2.51 | 1.25-4.49 | .01 | 262 | 13 | 1.48 | 0.79-2.53 | .22 |
| | 40-49 | 84 | 17 | 1.34 | 0.78-2.14 | .29 | 276 | 21 | 1.04 | 0.64-1.58 | .93 |
| | 50-74 | 88 | 33 | 1.01 | 0.70-1.42 | .99 | 245 | 55 | 0.91 | 0.69-1.19 | .56 |
| **Total** | | **316** | **66** | 1.26 | 0.98-1.61 | .07 | **1122** | **94** | 1.00 | 0.81-1.23 | .98 |
| 32 to <36 | 18-29 | 145 | 10 | 2.05 | 0.98-3.78 | .06 | 340 | 7 | 1.49 | 0.60-3.07 | .39 |
| | 30-39 | 128 | 14 | 1.20 | 0.66-2.02 | .56 | 285 | 16 | 1.47 | 0.84-2.39 | .17 |
| | 40-49 | 127 | 33 | 1.64 | 1.13-2.30 | .01 | 315 | 38 | 1.32 | 0.93-1.81 | .12 |
| | 50-74 | 148 | 60 | 1.14 | 0.87-1.47 | .33 | 372 | 104 | 1.12 | 0.91-1.35 | .29 |
| **Total** | | **548** | **117** | 1.31 | 1.09-1.57 | .005 | **1312** | **165** | 1.20 | 1.02-1.40 | .03 |
| 36 to <40 | 18-29 | 127 | 8 | 1.96 | 0.84-3.86 | .11 | 227 | 3 | 0.84 | 0.17-2.45 | .96 |
| | 30-39 | 78 | 15 | 3.21 | 1.79-5.29 | <.001 | 218 | 19 | 1.98 | 1.19-3.10 | .01 |
| | 40-49 | 71 | 17 | 1.81 | 1.05-2.89 | .03 | 260 | 30 | 1.31 | 0.88-1.87 | .18 |
| | 50-74 | 100 | 44 | 1.72 | 1.25-2.31 | .001 | 267 | 87 | 1.19 | 0.95-1.46 | .13 |
| **Total** | | **376** | **84** | 1.92 | 1.53-2.38 | <.001 | **972** | **139** | 1.27 | 1.07-1.50 | .007 |
| 40 to 75 | 18-29 | 102 | 13 | 4.22 | 2.24-7.21 | <.001 | 247 | 16 | 3.79 | 2.16-6.15 | <.001 |
| | 30-39 | 93 | 22 | 3.53 | 2.21-5.34 | <.001 | 292 | 37 | 3.29 | 2.32-4.54 | <.001 |
| | 40-49 | 102 | 38 | 3.67 | 2.60-5.04 | <.001 | 329 | 87 | 2.82 | 2.26-3.50 | <.001 |
| | 50-74 | 47 | 22 | 1.92 | 1.20-2.91 | .007 | 323 | 124 | 1.82 | 1.51-2.17 | <.001 |
| **Total** | | **344** | **95** | 3.05 | 2.47-3.73 | <.001 | **1191** | **264** | 2.31 | 2.04-2.60 | <.001 |

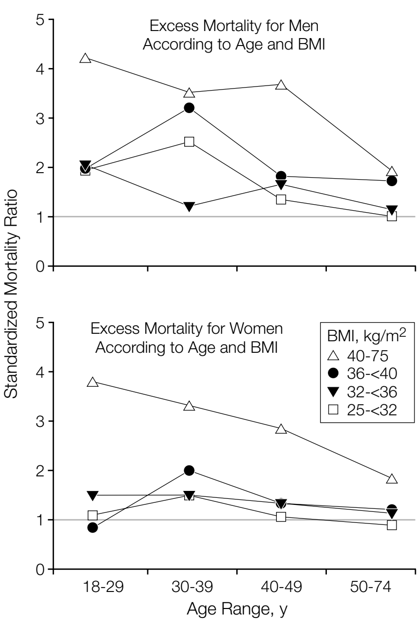
*BMI indicates body mass index; SMR, standardized mortality ratio; and CI, confidence interval.

**Figure 1.** Standardized Mortality Ratios for Obese Patients by Age Group




Data were calculated using the male and female populations of North Rhine Westphalia, Germany, as the reference populations. Obese patients had a body mass index of 25 to 75 kg/m$^2$. Error bars represent 95% confidence limits. A test for trend was significant ($P<.001$) for both sexes.

**Figure 2.** Standardized Mortality Ratios for Obese Patients by Age and BMI Groups




Data were calculated using the male and female populations of North Rhine Westphalia, Germany, as the reference populations. BMI indicates body mass index.

endar year. Although in total more than 6000 obese patients were recruited for a period of 33 years, the capacity to describe mortality in terms of dependence on sex, age, and BMI is limited. Considering 2 sexes, 4 age groups, and 4 BMI groups, the entire cohort is subdivided into 32 groups ($2 \times 4 \times 4 = 32$) of limited size. As expected, relatively few deaths were observed in the lower age ranges, leading to uncertain SMR estimates in these groups. Hence, for the estimated excess mortality associated with obesity dependent on age, some irregularities can be expected. The 32 SMR estimates must be interpreted simultaneously, taking the significant overall decreasing trend of the SMRs with age for both sexes into account.

Additional limitations of our study should be considered. First, the study cohort does not represent a random sample of the obese population; hence, recruitment bias may be a problem. Physician and self-referral patterns may vary among subgroups of the study cohort (eg, men vs women, age group, concomitant diseases or symptoms, health beliefs of patients and their physicians, or extent of obesity). It is fair to assume, however, that those obese patients referred to our obesity clinic tended to be more concerned about their health or had more problems concerning obesity-associated symptoms and diseases than the remaining population of grossly obese patients living in the same geographic area. This interpretation is supported by the high mean values of blood pressure and the high proportion of people with diabetes and impaired glucose tolerance in our cohort.

Second, information on putative confounders, such as smoking, alcohol consumption, medication, body fat distribution, obesity-associated symptoms, and psychological variables, as well as the patients' social status and physical activity level, was insufficient to be included in the analysis of this large cohort recruited during a period of 33 years.

Third, no systematic information is available regarding the course of obesity after recruitment of the patients. Thus, the possible effects of weight change could not be investigated. However, earlier analyses of subgroups of patients indicate that the overall long-term effect on weight reduction by our obesity clinic intervention was almost negligible; as in other comparable reports, approximately 50% of patients did not attend the therapeutic program after the initial examination and, for the remaining patients, a mean weight loss of about 9 kg was reached after a mean duration of 6 months. However, a significant long-term weight reduction was demonstrable in less than 5% of patients.[16]

Fourth, it was not possible to obtain reliable information on cause of death. According to the prevailing state law of North Rhine Westphalia, access was not available to the death certificates of the patients in this study.

Finally, it can be argued that SMR may decrease with increasing age simply because of an increase of the prevalence of obesity in the general population with increasing age.[22] Indeed, the population-based German Cardiovascular Prevention (GCP) Study demonstrated that the average BMI rises steadily with age in Germany.[23] We have estimated from the data of the GCP Study[24] that the prevalences of gross and morbid obesity (BMI $\geq$32 kg/m$^2$) in North Rhine Westphalia for the age groups of less than 30, 30 to 39, 40 to 49, and 50 or more years are about 4.2%, 5.9%, 8.8%, and 9.5% for men and 3.8%, 6.0%, 9.6%, and 20.4% for women, respectively. Thus, the prevalence of gross and morbid obesity increases by a factor of 2.3 in men and 5.4 in women when comparing subjects who were aged 50 years or older with those subjects younger than 30 years. To investigate the possible bias of the SMR due to the increasing prevalence of obesity with increasing age, we calculated the SMRs of gross and morbid obesity within the 4 age groups and compared the results with the RRs of exposed vs unexposed persons, estimated by means of the formula proposed by Jones and Swerdlow.[22] The

SMRs for the 4 age groups were 2.6, 2.3, 2.2, and 1.4 for men and 2.1, 2.3, 1.9, and 1.3 for women, respectively. The prevalence-adjusted RRs were 2.8, 2.5, 2.5, and 1.5 for men and 2.2, 2.5, 2.1, and 1.5 for women, respectively. Thus, after adjusting for the increasing prevalence of obesity, the decreasing trend of excess mortality related to gross and morbid obesity with increasing age did not disappear. Even the amount of excess risk decrease remained unchanged. Thus, we conclude that the observed decrease of the SMRs with increasing age cannot be attributed to the increasing prevalence of obesity with increasing age in the general population of North Rhine Westphalia. The SMRs represent estimations of the excess risk standardized for age and calendar year of the defined age-by-BMI groups with respect to the general population having a specific BMI distribution. One might be interested in estimating RRs of the study cohort with respect to a BMI-truncated section of the general population (eg, BMI $<20$ or $<25$ kg/m$^2$). For an appropriate estimation of these RRs, the population and mortality data of the BMI-truncated section of the general population are required. Such data, however, are not available.

Despite these limitations, our data complement recent results indicating that the RR associated with greater body weight declined with age in adults having a BMI distribution similar to that of a normal population.[14] Our data suggest that the excess mortality associated with greater BMI declined considerably with age in all degrees of obesity. This finding is plausible, given that a similar trend has been found in other conditions related to cardiovascular mortality, such as type 2 diabetes[25] and hypercholesterolemia.[26] Although the decrease of excess mortality with increasing age among extremely obese men was already suggested by Drenick et al,[2] no reliable estimates of excess mortality could be presented because of the low sample size; the estimated 12-fold excess mortality of obese men in subjects aged 25 to 34 years was based on only 3 deaths and may therefore represent an overestimation. Our data had sufficient size to show a significant decreasing trend of the SMRs with age in obese men and women, with a more reliable quantification of the excess mortality associated with obesity dependent on age. Especially in morbid obesity (BMI $\geq$40 kg/m$^2$), the excess mortality declined with age, from 4.2 to 1.9 for men and from 3.8 to 1.8 for women, when comparing the age group younger than 30 years with that of 50 years or older.

It is evident that the risk of death does not increase with BMI in elderly people. A simple argument is that the absolute risk of death increases with age and finally reaches 100%. Thus, it cannot be further increased by factors other than age. It has been suggested that obesity has some impact on mortality up to 80 years of age but not thereafter.[9] Our data provide information about the amount of excess mortality associated with several degrees of obesity in relation to sex and age. It could be estimated that to be male (in comparison with women at the same age and BMI), to be aged 19 years or younger (at the same BMI), or to have a BMI of about 4 kg/m$^2$ more (at the same age) increases the excess mortality by approximately the same extent. According to these estimations, obese women can have a BMI of about 4 kg/m$^2$ more than obese men, with approximately the same excess risk of death compared with the expected mortality for the general population. An increase in BMI of about 2.25 kg/m$^2$ per decade of life allows obese men and women to maintain a constant level of excess risk. For a 170-cm tall person, this would translate to a weight increase of about 6.5 kg per decade of life. This value is higher than the increased mean weight allowance of 4.5 kg per decade of life that is based on actuarial data.[27] Nevertheless, there seems to be no considerable difference between these results because the weight allowance per decade of life is probably not constant in all ranges of obesity and age. Although these estimates can give only a rough impression about the strength of the effects of sex, age, and BMI on mortality in obesity, they should have important consequences for rating systems in the field of health insurance policies.

No excess mortality was associated with a BMI of at least 25 but less than 32 kg/m$^2$ in the group aged 50 years or older for either men or women. These results are consistent with previous findings in a sample of the US population that the range of BMI with minimum mortality and low excess risk ($<$20%) is wide and includes 70% of the population.[28] Our study gives additional information about the excess risk of higher BMI groups dependent on age. A low excess mortality (SMR $<$1.2) was observed for women aged 50 years or older with a BMI of less than 40 kg/m$^2$ and for men aged 50 years or older with a BMI of less than 36 kg/m$^2$. In practice, such patients are often advised to lose weight even if they do not have any obesity-related diseases, such as type 2 diabetes, hypertension, and hypercholesterolemia; however, such dieting might unjustifiably decrease their perceived quality of life.

In summary, the excess mortality associated with obesity declined considerably with age for both sexes in all degrees of obesity.

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A witty friend of mine once remarked that the world thinks of the man of science as one who pulls out his watch and exclaims, "Ha! half an hour to spare before dinner: I will just step down to my laboratory and make a discovery." Who but men of science themselves are to blame for such a misconception? Out of the many memoirs which fill our libraries few recount the labours of investigators, even of those who seek to solve the secrets of the great maladies which annually destroy millions of us—surely a matter of interest to everyone. Our books of science are records of results rather than of that sacred passion for discovery which leads to them. Yet many discoveries have really been the climax of an intense drama, full of hopes and despairs, visions seen in darkness, many failures, and a final triumph: in which the protagonists are man and nature, and the issue a decision for all the ages.

—Sir Ronald Ross (1857-1932)

 