OBESITY AND EXCESS MORTALITY AMONG THE ELDERLY IN THE UNITED STATES AND MEXICO*

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Increasing levels of obesity could compromise future gains in life expectancy in low- and high-income countries. Although excess mortality associated with obesity and, more generally, higher levels of body mass index (BMI) have been investigated in the United States, there is little research about the impact of obesity on mortality in Latin American countries, where very the rapid rate of growth of prevalence of obesity and overweight occur jointly with poor socioeconomic conditions. The aim of this article is to assess the magnitude of excess mortality due to obesity and overweight in Mexico and the United States. For this purpose, we take advantage of two comparable data sets: the Health and Retirement Study 2000 and 2004 for the United States, and the Mexican Health and Aging Study 2001 and 2003 for Mexico. We find higher excess mortality risks among obese and overweight individuals aged 60 and older in Mexico than in the United States. Yet, when analyzing excess mortality among different socioeconomic strata, we observe greater gaps by education in the United States than in Mexico. We also find that although the probability of experiencing obesity-related chronic diseases among individuals with high BMI is larger for the U.S. elderly, the relative risk of dying conditional on experiencing these diseases is higher in Mexico.

In developing countries, particularly in Latin America and the Caribbean (LAC), rates of obesity and overweight are growing steadily and reaching levels similar to or even surpassing those of the United States and other high-income countries.[1] According to the World Health Organization (WHO Global InfoBase 2005), in 2005, the prevalence of obesity among women older than 30 was about 44% in Mexico and 49% in the United States; among men, these levels were 30% in Mexico and 42% in the United States.

In both Mexico and the United States, obesity prevalence experienced a sharp increase during the 1990s. According to Kain, Vio, and Albala (2003), the prevalence of obesity among adult women in Mexico jumped from 9% in 1988 to 24% in 1999. During the 1990s, obesity prevalence rates among U.S. adults older than 20 increased from 20% to 27% for men and from 25% to 33% for women (Flegal et al. 2002).

The increasing prevalence of obesity and overweight in LAC countries may be the result of a convergence toward lifestyles and diets that are commonplace in industrialized countries (Caballero 2001; Popkin 1994; Uauy, Albala, and Kain 2001). But this may be only part of the story. By and large, the association between socioeconomic status (SES)

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1. For the time being, we use the terms *obese* and *overweight* as is used throughout in the extant literature—namely, we use *obese* to refer to individuals whose BMI (weight/height^2) equals or exceeds 30 and *overweight* to refer to individuals with BMI equal to or exceeding 25 and lower than 30. In our analysis, we use slightly different definitions.

and obesity in LAC countries is negative even though one would expect westernization of lifestyles to proceed at a faster pace among those in higher socioeconomic strata. Monteiro, Conde, and Popkin (2004) showed marked differentials in the prevalence of obesity by SES for Brazil, with less-advantaged groups exhibiting greater obesity risks. In Mexico, obesity and overweight are highly concentrated in the poorest sectors of the population to a much larger extent than in other Latin American countries (Drewnowski and Specter 2004; Ferald et al. 2004; PAHO/OPS 2006; Zhang and Wang 2004).

Some authors (Palloni et al. 2006; Valiente et al. 1988) have suggested that in the LAC region in general, the combination of substandard nutrition in early childhood with sedentary lifestyles and excessive consumption of fat and cheap food staples throughout life may be a complementary explanation of the increased levels of obesity, diabetes, and atherosclerosis. Changes in the environment that led to metabolic adaptations of the body to allow it to function under conditions of low energy intake, and low-fat diets (early in life) may result in higher sensitivity to obesity and overweight at adult ages (Baschetti 1998, 1999; Caballero 2001). Obesity and overweight experienced by those in the poorest strata of a population may be of a different nature than obesity among the highest strata of the same population. In the latter groups, the factors accounting for the emergence of high levels of obesity and overweight may indeed be consistent with the standard explanation—namely, that the phenomenon is a function of excessive intake of animal fats and refined sugars accompanied by a low intake of fibers. But in the groups with lower socioeconomic standing, obesity and overweight could result from a combination of somewhat different factors involving lifelong conditions predisposing individuals to metabolic disorders, a diet lacking in essential micronutrients and proteins obtained from meat consumption, and a sharp drop of energy expenditure (Asfaw 2007; Drenowsky and Specter 2004; Peña and Bacallao 2000).

Research suggests that obesity and overweight are related to higher risks of diseases such as hypertension, diabetes, heart disease, and some types of cancer (WHO 2000). Indeed, developing countries have exhibited an overall rise in rates of noncommunicable diseases for which obesity is suspected to be a major risk factor (Caballero and Wang 2006). This association between obesity and poor health suggests that past and current trends in obesity and overweight may exert a nontrivial influence on current and future mortality levels and patterns as well as on the expected length of healthy life.

Although excess mortality due to obesity has been acknowledged and investigated in the United States (Allison et al. 1999; Flegal et al. 2005; Fontaine et al. 2003; Mokdad et al. 2004; Olshansky et al. 2005), the phenomenon has been vastly understudied in countries of LAC, a region where unusually rapid growth of obesity and overweight prevalence occurs in conjunction with a host of conditions that enhance the vulnerability of the obese population. First, it is entirely possible that the set of characteristic chronic diseases associated with obesity and overweight may be different in LAC countries (as well as in other low- to medium-income countries) than in high-income countries. This could be due to the different sources of the increased prevalence of obesity and overweight suggested above. Second, mortality risks associated with the chronic conditions for which obesity and overweight are the key risk factors may be higher because not only are health services and health care of poorer quality but also the ecology of diseases in low- to medium-income countries is quite different. Indeed, obesity, diabetes, and cardiovascular diseases coexist with relatively high prevalence of infectious and parasitic diseases. This mixture has the potential to create higher mortality risks among those affected by chronic diseases for which obesity and overweight are risk factors. Thus, if excess mortality among the obese and overweight in LAC is larger than in high-income countries, the difference may be rooted in (a) more serious chronic conditions induced by obesity and overweight and/or (b) higher mortality risks among those with chronic conditions promoted by obesity and overweight.

The aims of this article are to assess excess mortality at age 60 and older among the obese and overweight in Mexico and to compare it with excess mortality experienced in the

United States. The novelty of this study is twofold. First, we evaluate the effect of obesity and overweight on mortality in these two countries by using two nationally representative data sets that are strictly comparable. Second, we use conventional standardization techniques to decompose excess mortality risks and to identify the contribution of differences in the probability of experiencing obesity-related diseases and differences in the lethality of these chronic diseases.

DATA AND METHODS

Description of Data Sets

We use data from the Mexican Health and Aging Study (MHAS) and the Health and Retirement Study (HRS). The MHAS was designed to be comparable with the HRS, and both are nationally representative surveys of older people. To measure mortality at age 60 and older, we consider individuals 59 years and older for the MHAS and individuals 58 years and older for the HRS, and we assume that deaths occur in the middle of the exposure period. The MHAS baseline (2001) includes 7,880 targets and spouses aged 59 or older, of whom a total of 465 died during 2001–2003. MHAS includes self-reported data regarding height and weight, as well as on chronic conditions (self-reports). Anthropometric measures of height and weight were also obtained for a selected subsample. Comparing self-reports with the anthropometric measures, we observe close correspondence for height and weight. We use self-reported data in order to calculate the body mass index (BMI = weight in kg/(height in meters)^2), but the corresponding anthropometric values are used when self-reports are missing.

The HRS consists of nine waves, with interviews conducted every two years since 1992. In order to have comparable reference periods for both countries, we consider the fifth wave of the survey (carried out in 2000) as the baseline. For this wave, the sample includes 15,897 individuals aged 58 years and older, of whom a total of 2,511 died between 2000 and 2004. In the HRS, height and weight are self-reported, as are the remaining variables used in this analysis.

In both data sets, we use individual's weight status at baseline (2000 for HRS and 2001 for MHAS). If one employs the conventional (WHO-defined) standard cutoff points for BMI, the proportion of overweight ($25 \leq$ BMI < 30) and obese (BMI ≥ 30) individuals aged 59 years or older is higher in the United States than in Mexico (41% and 27%, respectively, in the United States versus 38% and 20% in Mexico), whereas the proportion of individuals who had normal body weight ($18.5 \leq$ BMI < 25) is slightly higher in Mexico (38% versus 31% in United States).

With regard to obesity-related noncommunicable diseases, we find that even though the self-reported prevalence of diabetes among individuals over age 59 is very similar in both countries (17% in Mexico and 18% in the United States), self-reports for hypertension and heart attack are higher in the United States (54% and 13%, respectively) than in Mexico (41% and 3%, respectively). Of course, some of these contrasts (particularly those for hypertension) may be the result of differential misreporting errors rather than the outcome of objective conditions prevailing in the two countries.

Measuring Obesity: Some Important Caveats

Measurement of overweight and obesity status, especially among the elderly, is a highly controversial issue. First, there is disagreement about whether BMI or alternative indicators are better measures of tissue adiposity, which is the underlying, latent trait or "quantity" we would like to assess. Some studies show that waist-to-hip ratio (WHR) is a much better anthropometric predictor of total mortality (Folsom et al. 2000) or of the risk of experiencing chronic diseases among the elderly (Lapidus et al. 1984). Other studies suggest that since waist circumference (WC) is a better predictor of visceral fat in older individuals than WHR (Snijder, van Dam, and Seidell 2005; Visscher et al. 2001), it should be used instead of other indicators in the analyses of mortality and of chronic illness risks. It is well known that there is a high correlation between BMI and more direct measures of adiposity, particularly WHR. But since WHR or, for that matter, WC are not reliable indicators of visceral adipose tissue volume (as measured by computed tomography) (Solomon and Manson 1997), the utilization of BMI in its place remains controversial. After a careful review of the epidemiological literature, Solomon and Manson (1997) concluded that the relative role played by BMI and WHR in shaping mortality risks is not settled yet. Neither of the data sets used in the present study includes measures of waist or hip assessments, so it is simply not possible to measure the latent trait using alternative indicators. Instead, we are constrained to focus our attention only on BMI with all the caveats that this choice requires.

Second, an additional layer of thorny difficulties relates to the appropriate cutoff points of the BMI distribution. The use of fixed BMI cutoff points to create categories (underweight, normal weight, overweight, obese, and morbidly obese) that presumably reflect tissue adiposity volume has been heavily criticized because of the influence of differences in body composition among different populations and age groups (Hubbard 2000; Snijder et al. 2005; Villareal et al. 2005). Researchers have found that the BMI cutoff points that reflect a higher risk of suffering obesity-related diseases are not homogeneous across different populations, and they do not always coincide with the fixed cutoff points proposed by the WHO. For example, Hubbard (2000) found that the relevant cutoff points were lower than the fixed ones among some Asian populations, while the relevant cutoff points were higher for Asian/Pacific Islanders. It has also been shown that populations with short stature may be considered "obese" at lower levels of BMI because those with short stature have higher levels of body fat at each level of BMI (López-Alvarenga et al. 2003). To make matters worse, there can be heterogeneity by age within the same population because the body's musculoskeletal properties change with the process of aging. Thus, some research shows that using identical cutoff points across ages to classify a population leads to estimates of the effects of overweight and obesity on mortality that tend to wane at older ages (Bender et al. 1999; Flegal et al. 2005) and that are only visible for very high levels of BMI (Stevens et al. 1998). While this could be the result of selective survival or of "protective" effects of higher levels of BMI at older ages, some argue that it is the result of measurement problems generated by the fact that a fixed cutoff across ages leads to misclassification of individuals whose body mass and skeletal structure change due to the aging processes itself (Grabowski and Ellis 2001; Mazza et al. 2007). For example, high levels of BMI among the elderly may not reflect higher levels of adiposity, but rather changes in height due to vertebral compression, loss of muscular tone, and postural changes (Villareal et al. 2005; WHO 1995).

The foregoing difficulties can be circumvented somewhat if we evaluate the sensitivity of our results to alternative measures of excess weight using BMI as the core metric. To do so, we estimate models using the standard definition of BMI cutoff points given by WHO as well as relative values of BMI according to quintiles. Table 1 shows the cutoff points for each definition. Experimentation with these different criteria suggests that the use of quintiles is more revealing for comparison purposes than the use of fixed cut points. In what follows and unless noted otherwise, the classification of individuals as obese or overweight will be a function of whether they belong to the last quintiles of their own population's BMI distribution.

Estimation of Excess Mortality and Decomposition

To study the effect that obesity and overweight—as defined in the previous section—have on mortality among people aged 60 and older, we estimate differences in the conditional probabilities of dying between individuals in the highest quintiles of BMI and individuals in the middle of the distribution (the third quintile). The status of an individual regarding body weight is evaluated at baseline (2000 for HRS and 2001 for MHAS). In a first step,

Table 1. Classification of People According to Weight Status as Defined by the World Health Organization (WHO) and by BMI Quintiles in the Mexican Health and Aging Study (MHAS) and the Health and Retirement Study (HRS)

WHO Definition		BMI Quintiles		
		Quintile	MHAS (2001)	HRS (2000)
Low Weight	BMI < 18.50	First	BMI < 21.90	BMI < 22.62
Normal Weight	25.00 > BMI ≥ 18.50	Second	24.70 > BMI ≥ 21.90	25.08 > BMI ≥ 22.62
Overweight	30.00 > BMI ≥ 25.00	Third	27.3.0 > BMI ≥ 24.70	27.37 > BMI ≥ 25.08
Obese	35.00 > BMI ≥ 30.00	Fourth	30.50 > BMI ≥ 27.30	30.30 > BMI ≥ 27.37
Morbidly Obese	BMI ≥ 35.00	Fifth	BMI ≥ 30.50	BMI ≥ 30.30

we calculate the differences in the age-specific conditional probability of dying for the whole population and for different educational groups (as an indicator of SES) between the two subpopulations. In a second step, we use an extension of Kitagawa's (1955) classic standardization procedure to decompose such differences into two components referred to as the *chronic disease* and *mortality* components.

The conditional probability of dying q_i between ages x_i and $x_i + 1$, for an obese individual i characterized by a vector of covariates $\mathbf{z}_i$ can be expressed as follows:

$$q_i(x_i,o_i,\mathbf{z}_i) = \Sigma_j\, q_i(x_i,o_i,\mathbf{z}_i,d_{ij}) \times \text{pr}d_{ij}(x_i,o_i,\mathbf{z}_i), \tag{1}$$

where $q_i(x_i,o_i,\mathbf{z}_i)$ is the probability of dying between ages x_i and $x_i + 1$, conditional on being obese (o) at age x_i and on a vector $\mathbf{z}_i$ (including k covariates); $q_i(x_i,o_i,\mathbf{z}_i,d_{ij})$ is the probability of dying between ages x_i and $x_i + 1$, conditional on being obese (o) at age x_i, on experiencing disease $j(d_{ij})$, and on vector $\mathbf{z}_i$; $\text{pr}d_{ij}(x_i,o_i,\mathbf{z}_i)$ is the probability of experiencing disease j at age x_i, conditional on being obese (o) at age x_i and on vector $\mathbf{z}_i$; and d_{ij} represents groups of obesity-related chronic conditions.

The subscript j refers not only to obesity-related chronic conditions, such as diabetes and cardiovascular diseases, but also to all possible combinations of those diseases (comorbidities), including not suffering any of them. Therefore, $\Sigma_j\, \text{pr}d_{ij}(x_i,o_i,\mathbf{z}_i) = 1$.

By the same token, we can express the probability of dying for normal weight individuals (n) between ages x_i and $x_i + 1$, given that she/he survived age x_i, and covariate $\mathbf{z}_i$, as follows:

$$q_i(x_i,n_i,\mathbf{z}_i) = \Sigma_j q_i(x_i,n_i,\mathbf{z}_i,d_{ij}) \times \text{pr}d_{ij}(x_i,n_i,\mathbf{z}_i), \tag{2}$$

where all quantities are for normal weight individuals and correspond to the definitions given earlier. Once again, $\Sigma_j\, \text{pr}d_{ij}(x_i,n_i,\mathbf{z}_i) = 1$.

Subtracting expression (2) from expression (1) and adding and subtracting the terms $[q_i(x_i,n_i,\mathbf{z}_i,d_{ij}) \times \text{pr}d_{ij}(x_i,o_i,\mathbf{z}_i)] \times 0.5$ and $[q_i(x_i,o_i,\mathbf{z}_i,d_{ij}) \times \text{pr}d_{ij}(x_i,n_i,\mathbf{z}_i)] \times 0.5$, we can write the total difference in the probabilities of death between obese and normal weight individuals as

$$q_i(x_i,o_i,\mathbf{z}_i) - q_i(x_i,n_i,\mathbf{z}_i) = \Sigma_j[(\alpha^o_{ij} - \alpha^n_{ij}) \times (1/2) \times (\beta^o_{ij} + \beta^n_{ij}) + (\beta^o_{ij} - \beta^n_{ij}) \times (1/2) \times (\alpha^o_{ij} + \alpha^n_{ij}) \tag{3}$$

where

$$\alpha^o_{ij} = q_i(x_i,o_i,\mathbf{z}_i,d_{ij})$$

$$\alpha^n_{ij} = q_i(x_i,n_i,\mathbf{z}_i,d_{ij})$$

$$\beta^o_{ij} = \text{pr}d_{ij}(x_i,o_i,\mathbf{z}_i)$$

$$\beta^n_{ij} = \text{pr}d_{ij}(x_i,n_i,\mathbf{z}_i)$$

Note that expression (3) is analogous to the difference between crude rates in two populations (Kitagawa 1955).[2] In our case α^o_{ij}, α^n_{ij} are the rates of occurrence of the event (death), and β^o_{ij}, β^n_{ij} are measures of population composition (in this case, composition by prevalence of chronic illness). This decomposition analysis enables us to evaluate the contribution of the *mortality* and *chronic disease* components to the total difference in mortality levels between obese and normal weight individuals. The first product on the right side of expression (3), $((\alpha^o_{ij} - \alpha^n_{ij}) \times (1/2) \times (\beta^o_{ij} + \beta^n_{ij}))$, yields the contribution of the *mortality* component; the second product, $((\beta^o_{ij} - \beta^n_{ij}) \times (1/2) \times (\alpha^o_{ij} + \alpha^n_{ij}))$, yields the contribution of the *chronic disease* component.

Estimation of Effects

We estimate conditional probabilities using two sets of regressions. The first one is a logistic regression to evaluate the probability of dying conditional on weight (BMI) status and other controls. The dependent variable equals 1 if the individual died during the period analyzed, and 0 otherwise. For the decomposition analysis, we also estimate the probability of dying conditional on weight status and on suffering obesity-related chronic diseases. The second regression is a multinomial logistic model to evaluate the probability of experiencing each disease conditional on weight status. The dependent variable in the multinomial model is constructed by combining obesity-related chronic diseases. Thus, the resulting categories of the dependent variable include each single disease and any of their possible combinations. Both sets of regressions include controls for demographic factors (age and sex), behavioral factors (smoking status), and low weight. The predicted probabilities of dying and of suffering from chronic diseases are then evaluated by setting the control variables at their mean values. Chronic diseases are included in the analysis if and when the effect of obesity on the probability of experiencing them is statistically significant ($p < .01$). In our analyses, we study the following conditions: cardiovascular diseases (CVD), diabetes, cancer, and respiratory disease. The group of CVD includes heart disease, heart attack, stroke, and hypertension. Because the effect of obesity on the probability of cancer is not statistically significant in either country and because the effect of respiratory disease is not significant for Mexico and is trivial for the United States, our final analyses consider only diabetes and CVD. As a consequence, we include four possible combinations of chronic disease states: neither CVD nor diabetes; CVD but not diabetes; diabetes but not CVD; and the presence of both conditions.

ANALYSIS OF RESULTS

The Effects of Excess Weight on Mortality in the United States and Mexico

As we anticipated, conditional probabilities of dying are sensitive to variations in the cutoff points used to define obesity and overweight (Tables 2 and 3). For both Mexico and the United States, the effect of higher levels of weight is not statistically significant when using the WHO cutoff points for BMI even when low weight and smoking status are controlled for. Furthermore, the sign of the coefficients for obesity and overweight are not in the expected direction.

2. Kitagawa's decomposition procedure was originally designed for crude rates. But it is applicable to the decomposition of differences between any type of statistics, S, that are functions of conditions-specific values of S and the composition of the population by such conditions (e.g., age, cause of death, and chronic conditions). The original complete expression for the decomposition includes a term involving interactions between "rates" and "composition" terms that can be eliminated by using as a standard the average of rates on the one hand and the average of composition on the other. There are other ways of eliminating the interaction term (Das Gupta 1978), but we utilize the simpler formulation above since the observed interaction turns out to be negligible (almost zero for all our estimations).

Table 2. Logistic Regression Predicting Death Between 2001 and 2003 in Mexico: Mexican Health and Aging Study (2001 and 2003)

	WHO			BMI Quintiles[a]	
Variables	Coefficient	*p* Value	Variables	Coefficient	*p* Value
Age	0.08	.000	Age	0.08	.000
Sex	–0.28	.016	Sex	–0.32	.007
Education	–0.02	.218	Education	–0.01	.354
Morbidly Obese	0.21	.392	5th quintile BMI	0.47	.028
Obese	–0.44	.023	4th quintile BMI	0.54	.009
Overweight	–0.34	.011	2nd quintile BMI	0.40	.050
Low Weight	0.23	.346	1st quintile BMI	0.99	.000
Smoker	0.17	.269	Smoker	0.13	.394
Constant	–7.81	.000	Constant	–8.34	.000

[a]The first quintile is BMI < 21.9; the second quintile is 21.9 ≤ BMI < 24.7; the third quintile is 24.7 ≤ BMI < 27.3; the fourth quintile is 27.3 ≤ BMI < 30.5; and the fifth quintile is BMI ≥ 30.5.

Table 3. Logistic Regression Predicting Deaths Between 2000 and 2004 in the United States: Health and Retirement Study (2000 and 2004)

	WHO			BMI Quintiles[a]	
Variables	Coefficient	*p* Value	Variables	Coefficient	*p* Value
Age	0.11	.000	Age	0.11	.000
Sex	–0.55	.000	Sex	–0.54	.000
Education	–0.04	.000	Education	–0.04	.000
Morbidly Obese	0.02	.856	5th quintile BMI	0.18	.032
Obese	–0.26	.001	4th quintile BMI	0.05	.576
Overweight	–0.34	.000	2nd quintile BMI	0.13	.085
Low Weight	1.14	.000	1st quintile BMI	0.66	.000
Smoker	0.65	.000	Smoker	0.64	.000
Constant	–8.25	.000	Constant	–8.61	.000

[a]The first quintile is BMI < 22.62; the second quintile is 22.62 ≤ BMI < 25.08; the third quintile is 25.08 ≤ BMI < 27.37; the fourth quintile is 27.37 ≤ BMI < 30.3; and the fifth quintile is BMI ≥ 30.3.

However, when we use relative cutoff points (quintiles), we identify significant excess mortality for the two highest BMI quintiles (the fourth and fifth quintiles) in Mexico and for the fifth quintile in the United States, relative to individuals who are in the third BMI quintile. This result in combination with the aforementioned problems associated with the use of fixed cutoff points is a powerful argument for using quintiles of BMI to classify individuals.

The main differences observed between Mexico and the United States are in the magnitude of the effects of excess of weight on mortality, which is much larger in Mexico even though the length of the reference period is shorter there than in the United States. Also, and significantly, the effects of excess weight in Mexico are statistically significant at lower levels of BMI (BMI ≥ 27.3) than in the United States (BMI ≥ 30.3). Why this should be so poses an intriguing question to which we have no ready answer.

Obesity and Excess Mortality in the United States and in Mexico

Using the estimated coefficients in Tables 2 and 3, we first calculate predicted conditional probabilities by BMI group. We then estimate the associated mortality rates and annualize them.[3] These are then used to calculate one-year conditional probabilities of dying in both countries and the corresponding age-specific relative differences of the conditional probability of dying between individuals in the highest quintiles of BMI and those in the third quintile of BMI. These relative differences are displayed in the graph at the top of Figure 1. The graph at the bottom of Figure 1 shows the same curves but distinguishing individuals with less than six years of formal education from those with six or more years of formal education in both the United States and Mexico.[4]

For the populations as a whole, the relative differences in the probability of dying between individuals in the highest quintiles of BMI (the fourth and fifth quintiles for Mexico, and the fifth quintile for the United States) and in the third quintile of BMI are much larger in Mexico than in the United States (Figure 1, top graph). For instance, for a 60-year-old individual, the relative difference is more than 60% in Mexico but 20% in the United States.

Are the relative differences in the probability of dying across relevant BMI categories larger in Mexico than in the United States for all levels of education? The bottom graph in Figure 1 shows that among less-educated individuals (with less than six years of formal education) aged 60–69, the relative differences in the United States are similar to those in Mexico (more than 60%). The most important differences between elderly people in Mexico and the United States are among people with higher levels of formal education (six or more years). For this subpopulation, the relative difference in the probability of dying between people in the two BMI categories at age 60 is about 15% in the United Sates and 60% in Mexico. It is remarkable that despite the fact that the overall relative differences in the probability of dying (between individuals in the highest quintiles and those in the third quintile of BMI) are larger in Mexico than in the United States, the gap by education is much larger in the United States.

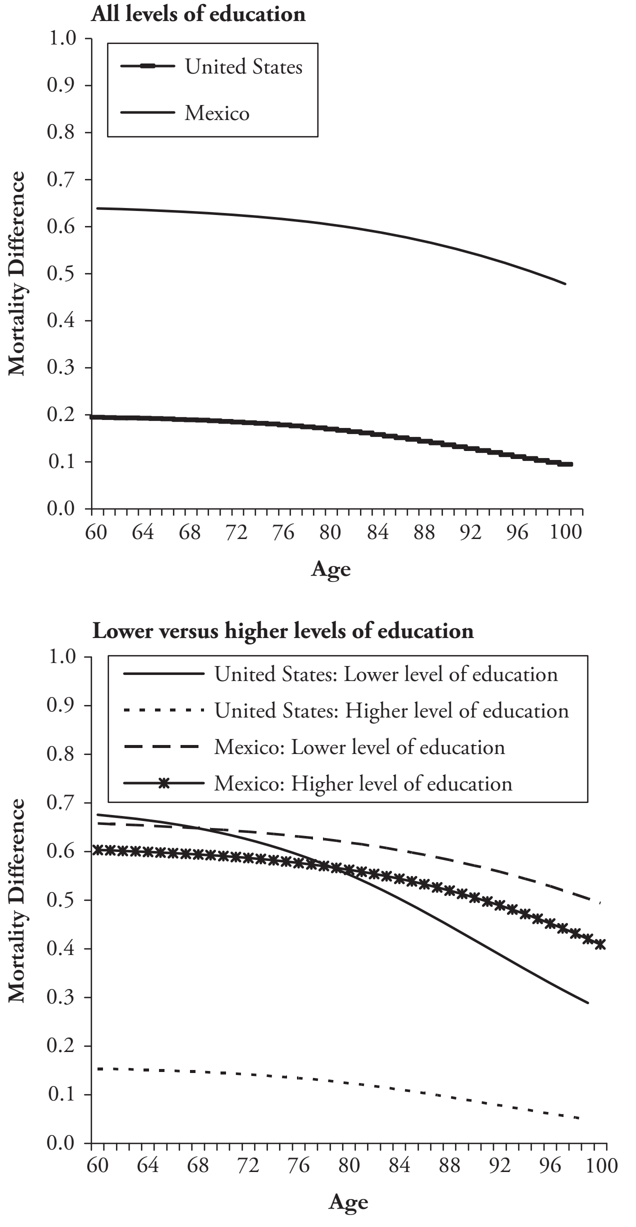
Decomposition of Excess Mortality Due to Obesity

To shed light on the mechanisms underlying the cross-country differences in excess mortality from obesity, we decompose the mortality differences between individuals in the two highest quintiles and those in the third quintile of BMI for the case of Mexico. For the United Sates, we decompose the mortality difference between those in the last and those in the third quintile. In each country, we choose the contrast between those quintiles associated with statistically significant effects. The decomposition breaks down mortality differences between individuals in the pertinent quintiles into two components: one due to chronic disease prevalence and the other due to mortality levels associated with the chronic disease. Mindful of the possibility that our results could be sensitive to the classification of individuals by BMI, we carry out a decomposition that considers alternative categories, and we use the contrasts between the fifth quintiles only in both countries. To calculate the components identified above we estimate two additional models: one estimating the probability of a chronic disease as a function of obesity, age, and other controls (chronic disease model), and a second one estimating the probability of chronic disease–specific mortality as a function of obesity, age, and other controls (mortality models). In each case, we estimate

3. Because HRS and MHAS have different interwave durations (four in the HRS and two in the MHAS), we need to annualize the rates to make the single-year conditional probabilities comparable between the two countries.

4. Having six or more years of formal education means to have completed at least primary school in Mexico and elementary school in the United States. Estimates of logistic models for different education categories are not shown but are available upon request.

Figure 1. Relative Differences in Mortality Between the Highest Quintiles of BMI and the Third Quintile of BMI: Mexico[a] and the United States[b]



Sources: Mexican Health and Aging Study (2001–2003) and Health and Retirement Study (2000–2004).

[a]In Mexico, the effect of excess of weight on mortality starts at the fourth quintile of BMI. Obese individuals are those in the fourth and fifth quintiles of BMI. Normal weight individuals are those in the third quintile of BMI in both Mexico and the United States.

[b] In the United States, the effect of the excess of weight on mortality becomes positive and statically significant at the fifth quintile of BMI. Consequently, only people in the highest quintile of BMI are included in estimates of the difference in life expectancy.

Table 4. Logistic Regression Predicting Deaths in the United States and Mexico (including obesity-related chronic conditions): Health and Retirement Study (HRS) and Mexican Health and Aging Study (MHAS)

	HRS (2000–2004)		MHAS (2001–2003)	
Variables	Coefficient	*p* Value	Coefficient	*p* Value
Age	0.11	.000	0.08	.000
Sex	–0.54	.000	–0.41	.001
Education	–0.03	.000	–0.02	.215
Fifth Quintile BMI	0.02	.817	0.45	.036
Fourth Quintile BMI	–0.02	.770	0.53	.011
Second Quintile BMI	0.16	.036	0.45	.029
First Quintile BMI	0.74	.000	1.11	.000
Smoker	0.70	.000	0.27	.080
Cardiovascular Diseases	0.42	.000	0.39	.004
Diabetes	0.42	.006	0.86	.000
Cardiovascular Diseases and Diabetes	1.19	.000	1.10	.000
Constant	–9.03	.000	–8.69	.000

Sources: MHAS (2001, 2003) and HRS (2000, 2004).

a version of the model with age and obesity entering additively and another one including interactions terms between age and obesity.

Tables 4 and 5 show the results of the (additive) mortality and chronic diseases models, respectively. After including obesity-related chronic diseases in the mortality model (Table 4), the direct effect of obesity on mortality is virtually eliminated in the United States but remains strong in Mexico. Table 5 shows that excess weight significantly increases the probability of suffering from obesity-related diseases.

When we introduce interactions between age and obesity in either the mortality or the chronic disease model, we observe that the pertinent variables are statistically insignificant in Mexico but significant only in the mortality model for the United States (results not shown). We also find that the overall fit of models with age-obesity interaction terms does not improve the goodness of fit of the model relative to the simpler, additive models. As a consequence, the decomposition exercise can be carried out independently of age, and we do so for the average age in each subpopulation aged 60 and older. The results are shown in Table 6. The table displays the magnitude of the contribution of the *chronic disease* component (first panel) and the *mortality* component (second panel) to the total difference in the risk of dying between obese and normal weight individuals. The contribution of each component is broken down by groups of chronic illnesses.

To dispel any doubts about the validity of the decomposition results, we repeated the analysis, estimating each component from models that included the interaction between age and the dummy variables for quintiles of BMI. Figure 2 displays the size of the each component by age for the United States (the country where such interaction terms were statistically significant) and Mexico (where the interaction terms were not statistically significant). The figure shows that there is almost no variation by age and, therefore, that the decomposition at the mean should provide a very good approximation to the magnitude of each component. Because the interactions terms are not statistically significantly different from zero for Mexico, the decomposition exercise carried out by age produces components that are age invariant, equal to the mean, and thus equal to those in Table 6 for all ages.

Table 5. Multinomial Logistic Regression Predicting Groups of Diseases[a] in the United States and Mexico: Health and Retirement Study (HRS) and Mexican Health and Aging Study (MHAS)

	HRS (2000)		MHAS (2001)	
Diseases	Coefficient	*p* Value	Coefficient	*p* Value
Cardiovascular Diseases				
Age	0.05	.000	0.01	.001
Sex	–0.09	.019	0.53	.000
Education	–0.02	.000	0.01	.065
Fifth quintile BMI	0.56	.000	0.43	.000
Fourth quintile BMI	0.25	.000	0.19	.043
Second quintile BMI	–0.14	.012	–0.22	.019
First quintile BMI	–0.35	.000	–0.29	.003
Smoker	–0.21	.000	–0.55	.000
Constant	–2.41	.000	–2.07	.000
Diabetes				
Age	0.01	.066	–0.02	.034
Sex	–0.55	.000	0.24	.024
Education	-0.05	.001	0.00	.692
Fifth quintile BMI	0.62	.000	0.07	.663
Fourth quintile BMI	0.34	.018	0.03	.871
Second quintile BMI	–0.38	.019	–0.12	.442
First quintile BMI	–0.57	.001	–0.33	.061
Smoker	–0.41	.015	–0.23	.108
Constant	–1.77	.001	–1.07	.061
Cardiovascular Diseases and Diabetes				
Age	0.04	.000	0.00	.451
Sex	–0.16	.005	0.64	.000
Education	–0.08	.000	0.01	.264
Fifth quintile BMI	1.38	.000	0.48	.001
Fourth quintile BMI	0.68	.000	0.31	.028
Second quintile BMI	–0.32	.001	–0.20	.178
First quintile BMI	–0.71	.000	–0.22	.150
Smoker	–0.27	.003	–0.82	.000
Constant	–2.82	.000	–2.83	.000

[a]The reference category is suffer neither vascular diseases nor diabetes.

For the United States, the effect of obesity on mortality is thoroughly dominated by the higher probability among obese individuals of experiencing the chronic diseases we consider here. Indeed, close to 90% of the total difference in the probability of dying between individuals in the fifth quintile and those in the third quintile of BMI is due to the chronic disease component. The sizable contribution of this component in the United States is mainly due to the higher probability among obese people of suffering jointly

Table 6. Decomposition Analysis of the Total Difference of the Probability of Dying Between Obese and Normal Weight Individuals at Age 60 and Older: Mexico and the United States

Decomposition Components	Mexico (MHAS, 2001–2003): Excess Weight, Fourth or Fifth Quintiles of BMI	Mexico (MHAS, 2001–2003): Excess Weight, Fifth Quintile of BMI	United States (HRS, 2000–2004): Excess Weight, Fifth Quintile of BMI
Contribution of Chronic Disease Component (%)			
Absence of cardiovascular diseases and diabetes	–9.63	–13.60	–47.75
Cardiovascular Diseases	10.75	16.33	3.34
Diabetes	–2.51	–3.45	1.20
Cardiovascular diseases and diabetes	9.85	11.49	133.50
Total chronic disease component (A)	8.46	10.77	90.29
Contribution of Mortality Component (%)			
Absence of cardiovascular diseases and diabetes	28.68	27.14	1.69
Cardiovascular diseases	33.19	33.22	4.76
Diabetes	10.45	9.97	0.29
Cardiovascular diseases and diabetes	19.22	18.90	2.97
Total death component (B)	91.54	89.23	9.71
Total (A + B)	100.00	100.00	100.00
Predicted Probabilities			
Predicted probability of dying among obese individuals (C)	.024	.023	.032
Predicted probability of dying among normal weight individuals (D)	.014	.014	.027
Total difference (C – D)	.010	.009	.005

Note: The predicted probabilities of dying and of suffering from the chronic diseases were evaluated at the mean value of the independent variables (sex, age, years of education, and smoking).

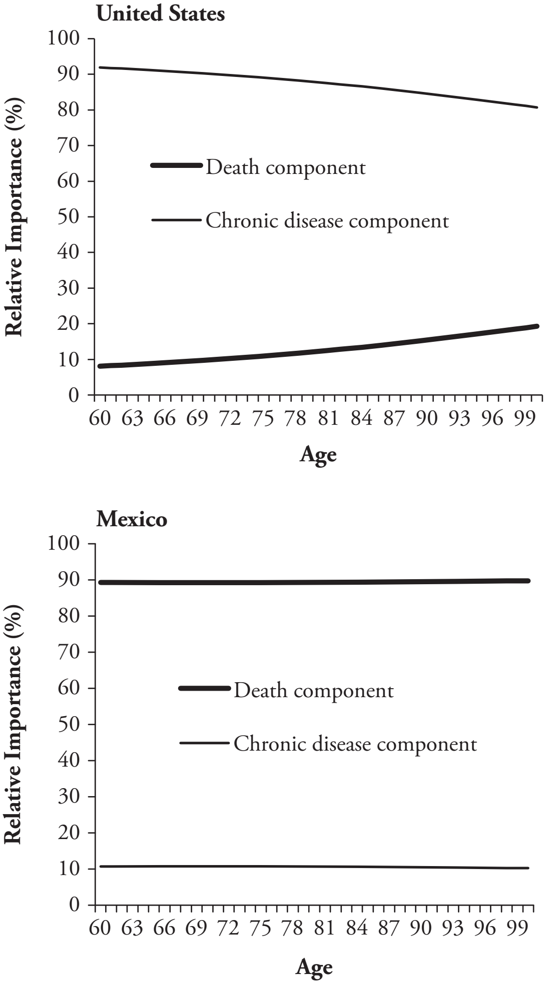
from diabetes and cardiovascular diseases. By contrast, in Mexico, the most important mechanism appears to be the higher mortality risk experienced by obese individuals. The mortality component accounts for close to 90% of the total difference in the probability of dying in Mexico versus 10% in the United States. The differences in mortality risks in Mexico between obese and normal weight people are especially high among individuals who suffer from cardiovascular diseases, which explain 33% of the total excess mortality. In Mexico, the risks of mortality are much higher than among normal weight people *even among obese individuals who do not report obesity-related chronic diseases*. Indeed, this last component alone explains about 28% of the total difference in the mortality risks between the two groups.

The results in Table 6 also show that the decomposition results are invariant to the categorization of BMI in quintiles.

DISCUSSION

Using a relative measure of excess body fat derived from the BMI distribution by subpopulations, we find a strong effect of excess weight on the risk of mortality among individuals aged 60 and older in Mexico and in the United States. Our findings indicate significantly higher mortality among elderly persons with a BMI of 30.3 and over in the

Figure 2. Mortality Component and Chronic Diseases Component by Single Ages in the United States and in Mexico



Sources: Mexican Health and Aging Study (2001–2003) and Health and Retirement Study (2000–2004).

United States and among those with a BMI of 27.3 and over in Mexico compared with elderly persons in the middle of the distribution of BMI (25.08–27.37 for the United States and 24.7–27.3 for Mexico).

The effect of excess weight is larger in Mexico than in the United States for the entire elderly population, irrespective of age. For instance, the relative difference in the probability of dying at age 60 between individuals in the fifth quintile and those in the third quintile of BMI is 20% in the United States. In Mexico, the difference is about three times larger. These relative differences tend to diminish slightly by age, but they are largely age invariant, and the differences of differences between the United States and Mexico are virtually unchanged as age increases (see Figure 1).

In contrast, the differences in mortality associated with excess weight tend to vary by educational level, a coarse indicator of SES. Our findings suggest that at least part of the higher effects in Mexico could be due to differences in educational composition between the cohorts aged 60 and over in the two countries. To divide the samples into low-educated and high-educated individuals, we used only one cutoff point (six years of formal education) in both countries, which led to sufficient number of cases for meaningful comparisons. This is a pragmatically driven decision, and it does not carry with it the belief that these subgroups are strictly comparable across countries. Among less-educated individuals aged 60–69, the relative differences in the probability of dying by weight status in the United States are very close to those observed in Mexico (more than 60% in both cases). Among people with higher levels of formal education, the differences among countries are substantial. Thus, for example, the relative difference between normal and overweight individuals in the conditional probability of dying at age 60 is about 15% in the United Sates and about 60% in Mexico.

Are our results comparable to others obtained by other researchers? Recent findings in the literature show significant effects of obesity on losses of life expectancy for the United States. Thus, Olshansky et al. (2005) estimated losses in life expectancy at birth by calculating the reduction in the probability of death that would occur if all overweight or obese respondents were to attain their "optimal" BMI. According to their results, the loss of life expectancy at birth in the United States due to obesity falls in a range between one-third to three-fourths of a year. On the other hand, Fontaine et al. (2003) estimated the differences in life expectancy between non-obese and obese people. According to their estimates, the difference in life expectancy at age 60 between normal weight (BMI = 24) and severely obese people (BMI $\geq$ 45) is five years for white women and six years for white men.

We first use cutoff points identical to those used by Fontaine et al. (BMI = 25 and BMI = 45) and estimate age-specific conditional probabilities of dying for individuals aged 60 and older in the United States by weight status (at baseline). We then estimate the life expectancies associated with each of the two sets of conditional probabilities of dying by age and calculate differences in life expectancy between individuals with BMI = 24 and severely obese people (BMI $\geq$ 45). Our estimates show differences in total (men and women) life expectancy at age 60 of about 6.7 years for the United States and 7.7 for Mexico. The results for the United States are very close to those obtained by Fontaine and colleagues.

We then follow a counterfactual analysis identical to that used by Olshansky et al. (2005) and estimate losses in life expectancy in the population at age 60 by assuming that a given set of mortality risks are "optimal." To do so, we simply set the conditional probabilities of dying at age 60 and older among individuals in the highest quintiles of BMI (the fifth quintile for the United States and the fourth and fifth quintiles for Mexico) at levels observed among individuals with "optimal" BMI (the third quintile). The results of removing excess mortality risks among people in the higher quintiles of BMI indicates that the total life expectancy at age 60 would be almost 2 years higher for Mexico and just about 0.55 years higher for the United States. Thus, whatever metric we use yields the same results: excess mortality among those classified as obese or overweight is higher in Mexico than in the United States.

Note that the estimates of losses of life expectancy estimated by Olshansky et al., those from Fontaine et al., and those calculated from our data were produced by applying a sequence of age-specific conditional probabilities of dying associated with each BMI group to obtain life expectancies at specific ages. These estimates apply to individuals who are assumed to remain in the initial state (obese or non-obese) for the rest of their lives. It is a strong counterfactual, but one that provides a sense of magnitude for excess mortality risks even though it does not really represent the length of life that a typical obese individual at age x is expected to live thereafter.

Is the higher relative risk of mortality observed in Mexico a result of the higher probability of suffering obesity-related diseases, or is it a consequence of the higher relative risk of mortality associated with these chronic diseases? According to the decomposition analysis, despite the fact that the probability of suffering obesity-related chronic diseases among individuals in the highest quintile of BMI (as compared with people in the third quintile of BMI) is much higher among the elderly in the United States than it is in Mexico, the relative risk of dying conditional on experiencing these diseases is higher in Mexico. Why should this be the case?

The higher prevalence of obesity-related chronic conditions in the United States and the lower level of lethality of these conditions may be the results of better diagnoses as well as better treatment and adherence to treatment. Indeed, Flegal et al. (2005) showed evidence of substantial improvements in the treatment of obesity-related chronic diseases in the United States, which contribute to reductions in the lethality of these conditions.

But the higher probability of experiencing chronic conditions in the United States might also be due to an artifact produced by greater accuracy of self-reported conditions, itself a result of better access to and use of medical care. However, for this to explain our findings, the accuracy of self-reported conditions would have to vary by the groups being compared (obese versus normal weight individuals). If both groups underreport at the same rate, one cannot argue that the magnitude of the chronic disease component in Mexico is attributable to underreporting. Thus, the case for an artifact produced by self-reports is a weak one.

There is another, more intriguing explanation for the findings unearthed by the decomposition analysis. The excess prevalence of chronic conditions in the United States may reflect a naturally occurring phenomenon whereby obese people in high-income countries are more likely to experience a host of chronic conditions than those in low-income countries (Burke et al. 2001) simply because of the different stages these countries occupy in the health transition. Higher mortality among obese Mexicans may be due to a combination of factors. First, inferior access to health services could disproportionally affect those who suffer chronic conditions more often (obese individuals). Second, other forces might induce increases in mortality for obese individuals in Mexico without necessarily increasing the incidence of chronic conditions. For instance, excess mortality may be the result of a double exposure to infectious and parasitic diseases that could aggravate the standard course of chronic diseases. The latter interpretation is consistent with the belief that the ecology of diseases (a combination of infections and chronic conditions) in Mexico, a feature that is quite unique to low-income countries (Monteverde, Noronha, and Palloni 2009; Palloni et al. 2006), is more likely to yield higher mortality among the obese without necessitating a pathway operating through chronic conditions.

Could potential future increases in obesity prevalence among the elderly affect mortality risks to the point of reversing past trends of gains in the life expectancy at older ages? Gregg et al. (2005) showed that changes in behavioral patterns and improvements in medical technologies in the United States have led to substantial declines in the prevalence of obesity-related chronic diseases (such as hypercholesterolemia and high blood pressure). Thus, despite the increases in obesity in the United States, all evidence points to an attenuation of the effect of obesity on mortality over time (Flegal et al. 2005). Preston (2005) also noted the importance of cohort effects in the United States. Compared with older cohorts, younger cohorts are exposed to factors—such as higher educational levels, lower exposure to infectious diseases that affect the development of chronic diseases during adulthood, and lower consumption of cigarettes—that decrease morbidity and have a positive influence on longevity. However, it is by no means unthinkable that sufficiently high rates of increases in the age-specific prevalence of obesity could offset these positive influences unless changes toward healthier lifestyles are adopted by the U.S. population (Preston 2005).

It is not clear that younger cohorts in Mexico (or in any other country in the LAC region for that matter) are exposed to such benign improvements of mortality regimes. It is more likely that it is in these countries where the increase in obesity will take a larger toll. Indeed, although educational levels have increased steadily over the past 50 years, these populations are still exposed to a higher share of infectious diseases that affect the unfolding of adult chronic diseases, have not achieved the same living standards (particularly nutritional standards) as their counterparts in high-income countries, and are just now being exposed to the consequences derived from increased uptake rates of smoking. According to projections from the WHO (2005), the prevalence of obesity in Mexico is expected to increase by 52% among men and by 24% among women aged 30 and older between 2002 and 2010. Unless Mexico and LAC countries experience medical improvements, like those observed in the United States, that partially negate the deleterious effects of obesity, longevity among older individuals may be compromised in the future.

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