Body Composition and Mortality in Mexican American Adults: Results from the National Health and Nutrition Examination Survey

Carrie R. Howell1, Tapan Mehta2, Keisuke Ejima3,4, Kirsten K. Ness1, Andrea Cherrington5 and Kevin R. Fontaine6

Objective: Epidemiologic analyses indicate a lack of association between BMI (kg/m²) and mortality among Hispanic adults. Because BMI provides only a surrogate for the real variable of interest, adiposity, this study evaluated associations between measures of body composition and mortality.

Methods: Using data from US-residing Mexican Americans in the National Health and Nutrition Examination Survey (NHANES) III (n=4,480) and NHANES 1999-2010 (n=5,849), the associations between seven measures of body composition measured via anthropometry and bioelectrical impedance analysis (i.e., waist circumference, waist to height ratios [WHtR], skinfolds, lean mass, fat mass, percent body fat, and BMI) and all-cause, cardiovascular, and diabetes mortality were examined. Additional analyses were stratified by gender.

Results: Waist circumference (hazard ratio [HR]: 1.04, 95% CI: 1.01-1.07) and WHtR (HR: 1.08, 95% CI: 1.03-1.14) were weakly associated with an increased all-cause mortality, while WHtR was associated with an increased risk of diabetes-related death (HR: 1.26, 95% CI: 1.07-1.49). In gender-stratified analyses, there was an increased risk of mortality in females who had increases in WHtR and waist circumference for all-cause mortality and cardiovascular deaths.

Conclusions: Waist circumference and WHtR were associated with increased risk of all-cause and diabetes-related mortality in US-residing Mexican American adults.

Introduction

The association between BMI (kg/m²) and mortality has been frequently examined across gender, race, and disease groups (1–4). Because BMI does not take into account potential variability in the proportion and distribution of either fat mass or lean mass (5), investigators have suggested that other measures of adiposity may provide more accurate estimates of the association between obesity and mortality (6). These include measures derived from bioelectrical impedance analysis (BIA), anthropometrics (e.g., skinfold thickness, waist circumference, waist to height ratio [WHtR] waist to hip ratio), and dual energy x-ray absorptiometry (DXA).

Although studies have shown that elevated BMI consistently associates with mortality in white and black populations (4,7), it does not do so among Hispanic adults (2,3). Studies have indicated that more precise measures of adiposity, such as ratio measures (e.g., waist to hip, waist to thigh, waist to height), may be stronger predictors of mortality (6), diabetes (8), and cardiovascular disease (CVD) (9) than BMI in white and black individuals, while lean mass has been shown to play a protective role in mortality risk (1).

Ethnic and racial differences in body composition also facilitate the need to investigate different indices of adiposity. Hull et al. (10) examined the differences in fat-free mass index (fat-free mass/height²) between gender, age, and ethnic groups and found that Hispanic men and women both had significantly higher fat-free mass index values than white and Asian individuals but lower values than black individuals. However, Aleman-Mateo et al. (11) found that total body and truncal fat was higher and fat-free lean

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mass was significantly lower in Mexican Americans compared with their white and black counterparts. Given differences in body composition as a function of race/ethnicity as well as variation in findings of fat and lean mass distributions, using BMI as a proxy measure of obesity may not provide a precise estimate of the obesity–mortality association among Hispanic people. Furthermore, certain subgroups, such as Mexican Americans, may exhibit different obesity–mortality associations.

Here we examine the association between measures of body composition and all-cause and cardiovascular- and diabetes-related mortality among US-residing Mexican American adults who participated in the National Health and Nutrition Examination Survey (NHANES) in 1988 to 1994 (NHANES III) and 1999 to 2010 (NHANES 1999-2010). We hypothesize that measures of adiposity, such as waist circumference, WHtR, and percent body fat, will associate with all-cause and cardiovascular- and diabetes-related mortality among Mexican Americans.

**Methods**

**Data source**

We used data from NHANES (12), a program of surveys and physical examinations sponsored by the Centers for Disease Control and Prevention (CDC) and conducted for more than 50 years in the United States. NHANES was designed to provide population estimates related to nutrition and health of US residents aged 2 months and older (age 0 and older since NHANES 1999-2000). Two data sets were used: NHANES III, conducted from 1988 to 1994, and the continuous NHANES, specifically data collected from 1999 to 2010. Publicly available mortality data were probabilistically matched (to ensure anonymity) using the National Death Index to each participant through December 31, 2011 (13). Data are publicly available from the CDC website (12). This project was reviewed and declared exempt (i.e., the research conducted was less than minimal risk and used publically available deidentified data) by the University of Alabama at Birmingham institutional review board.

**Inclusion criteria**

Sampling of non–Mexican American Hispanic participants was smaller than the US population in the design of NHANES III and NHANES 1999-2007. Because of this, the National Center for Health Statistics (14) recommends limiting analyses to Mexican Americans for NHANES prior to 2007 for precise estimates. Specific criteria for inclusion in the analyses were as follows: Mexican American adults who 1) were aged 20 years or older, 2) were not pregnant at the time of assessment, 3) completed the physical examination and home questionnaire portions of NHANES, and 4) were not missing mortality data. We identified 11,051 (unweighted sample size) Mexican American adults who were aged 20 or older and excluded 303 (unweighted) pregnant females, 410 (unweighted) individuals who had some missing exam or questionnaire data, and 9 (unweighted) individuals missing mortality information, leaving an unweighted sample of N=10,329 participants for analysis.

**Study variables**

**Outcome variables.** Survival time, with age in years as time scale, to all-cause, cardiovascular-related, or diabetes-related death or to censoring (December 31, 2011) was the primary outcome of interest, with a classical approach accounting for competing risks by coding deaths due to other causes as censored at the time of death for each cause-specific death. Cardiovascular deaths were defined using International Classification of Diseases, Tenth Revision codes I00-I09, I11, I13, and I20-I51, and diabetes deaths were defined using codes E10-E14.

**Predictor variables.** Predictors of interest included six measures of body composition: 1) waist circumference (centimeters), 2) WHtR, 3) sum of subscapular and triceps skinfolds (millimeters), 4) lean mass (kilograms), 5) fat mass (kilograms), and 6) percent body fat collected via BIA (for the continuous NHANES, we restricted the analysis of lean mass, fat mass, and percent body fat to the NHANES 1999-2004 cycles because BIA was not collected in the 2005-2010 cycles). An additional model was fitted with BMI as a predictor. Waist circumference, weight, height, and skinfold thickness were collected using standard equipment by trained NHANES staff based on uniform procedures (15). WHtR was calculated by dividing waist measurement in centimeters by height in centimeters. BMI was calculated as weight in kilograms divided by height in meters squared.

BIA was collected by placing electrodes on the participant’s right hand and right foot and administering a small electrical current, while additional electrodes placed on the right side of the body measured the resistance and reactance to the current (16). Resistance and reactance values were recorded and then converted to assess body composition values such as fat-free body mass and total body water using established formulas (17).

**Covariates.** Covariates (age, gender, and smoking status) were selected a priori and included potential confounders related to associations between mortality and body composition. Age was treated as a continuous variable in the model. Gender and smoking status were categorical, with smoking status classified as never smoker, former smoker, or current smoker.

**Statistical analysis**

Means, proportions, and measures of variation were calculated, taking into account the complex, stratified sampling design used by NHANES by applying weights, strata, and sampling unit values to produce estimates of the national population. Hazard ratios (HRs) and 95% CIs were calculated using Cox proportional hazards regression, with all-cause mortality and cardiovascular- and diabetes-related mortality as the outcomes and age at death or censor as the time scale (18), for each measure of adiposity in separate models. Reference cutoff values for each anthropometric measure were computed by following the prevalence-matched approach, similar to methods used by Flegal and Graubard (19). First, we calculated the proportion of adults in our sample with BMI≤25 kg/m² and BMI>25 kg/m². Next, we looked at the distributions of each of the body composition measures and selected a cutoff that would yield the same proportion in our sample to match the distribution based on BMI. To assess nonlinearity of the continuous body composition measures, an additional analysis was conducted by entering quadratic terms into each of the models for each mortality outcome. We assessed the improvement (or the lack of improvement) in model fit using the Akaike information criterion (AIC). To control for varying times of entry into the study (18), we left truncated the survival observation period for each participant at the age at survey. The age at survey
was included as a covariate in the models, along with, as previously noted, gender and smoking status. Proportional hazard assumptions were assessed using weighted Schoenfeld residuals (20) and weighted Kaplan-Meier curves and appeared reasonable for the covariates in the model. Because of established differences in body composition by gender, an additional stratified analysis was conducted to ascertain any gender differences in the association between body composition/adiposity and mortality. We also conducted an additional analysis that estimated HRs based on 5-unit increment increases per body composition measure.

To compare the predictive ability of the models, a generalized R² was calculated using methods described by O’Quigley et al. (21), where the Cox and Snell (22) R² is adjusted by the number of censored events as opposed to the overall sample size and is more appropriate when data are highly censored. Kent (23) proposed the use of a “coefficient of explained randomness” in nonlinear models, such as the Cox proportional hazards model, which is comparable to explained variation in linear models and often referred to as a generalized or pseudo-R². A higher number indicates a higher level of explained randomness (because these models are proportional) for that particular model. We used R version 3.4.0 (R Foundation for Statistical Computing, Vienna, Austria) and its library (“surv”) to conduct all analyses.

Results

Descriptive statistics for the sample are presented in Table 1 (shown separately by data set). There were 10,329 Mexican American adults (unweighted sample size) included in the analysis, with a mean age of 38.7 years (SD 14.2) at time of study participation, and roughly 47% were female. After a mean follow-up of 11.0 years (SD 6.9), there were a total of 1,423 unweighted deaths, of which 109 were cardiovascular-related deaths and 107 were diabetes-related deaths. Mean age at all-cause mortality was 64.7 years (SD 17.0); cardiovascular-related mortality was 65.9 years (SD 19.6); and diabetes-related mortality was 69.7 years (SD 12.7).

Plotted HRs for all-cause, cardiovascular-related, and diabetes-related mortality by continuous body composition measure for the 1-unit linear models are presented in Figure 1. Estimates for the 1-unit linear and quadratic models for all-cause mortality, along with model fit statistics, are presented in Supporting Information Table S1, with estimates for cardiovascular- and diabetes-related deaths presented in Supporting Information Table S2. Overall, after adjusting for gender, smoking, and age, waist circumference and WHtR associated with a slight increased risk of all-cause death among Mexican American adults, while no other measure of body composition associated with an increased risk. No body composition measures associated with an increased risk of cardiovascular-related death. WHtR was associated with an increased risk of diabetes-related death.

Table 2 presents HR mortality estimates for larger increases (which may translate into more clinical relevance) in the various body composition measures. As shown, it is estimated that Mexican American adults have a 4% increased risk for all-cause mortality for each 5-cm increase in waist circumference and an 8% increased hazard of death per 5% (0.05) increment increase in WHtR. Sum of skinfolds, percent body fat, fat mass, lean mass, and BMI did not associate significantly with all-cause mortality (HR: 0.97-1.06). Mexican American adults had a 26% increased risk of diabetes-related death per 5% (0.05) increment increase in WHtR, while no measure of body composition associated significantly with cardiovascular-related mortality.

**Gender-specific estimates.** Because substantial gender differences in body composition exist, we conducted a stratified analysis by gender for both data sets (Figure 2 and Table 3). Figure 2 plots the HRs for mortality by body composition measure on a continuous scale (per 1-unit increment) for males and females separately. Table 3 presents HR mortality estimates for 5-unit increases for each body composition measure for males and females.

There were no significant associations between body composition and all-cause and diabetes-related mortality in Mexican American male participants. However, per 5-unit increases in BMI, sum of skinfolds, percent body fat, and fat mass, males had reduced risk of cardiovascular-related mortality. For every 5-unit increase in waist circumference, Mexican American females had an increased risk of all-cause mortality (HR: 1.06; 95% CI: 1.01-1.10) while a 5-unit climb in WHtR increased the risk of all-cause and diabetes-related mortality (HR: 1.11; 95% CI: 1.04-1.18 and HR: 1.24; 95% CI: 1.05-1.48, respectively). Interestingly, Mexican American females who had increases in BMI (HR: 1.37; 95% CI: 1.11-1.69), waist circumference (HR: 1.15; 95% CI: 1.05-1.26), WHtR (HR: 1.26; 95% CI: 1.10-1.44), and lean mass (HR: 1.58; 95% CI: 1.21-2.08) exhibited an increased risk in cardiovascular-related mortality.

### Table 1 Description of the data sets and participant characteristics

| Characteristics | NHANES III | NHANES 1999-2010 |
|-----------------|-----------|-----------------|
| **Dates of study** | 1988-1994 | 1999-2010 |
| **Sample size for analysis** | 4480 | 5849 |
| **Mean age (y)** | 37.4 (14.4) | 39.5 (14.1) |
| **Mean mortality follow-up (y)** | 18.7 (4.1) | 6.4 (3.3) |
| **Female (%)** | 47.8 | 45.7 |
| **Number of deaths (%)** | 999 (13.9) | 424 (3.4) |
| **Mean BMI (kg/m²)** | 27.4 (5.4) | 28.9 (5.9) |
| **Mean waist circumference (cm)** | 92.4 (13.3) | 96.9 (13.9) |
| **Mean WHtR (SE)** | 0.57 (0.08) | 0.59 (0.09) |
| **Mean sum skinfolds (cm)** | 39.3 (15.8) | 38.7 (13.7) |
| **Mean BIA % fat (kg/m²)** | 31.6 (8.8) | 31.4 (10.6) |
| **Mean BIA lean mass (kg)** | 50.0 (10.8) | 52.0 (12.3) |
| **Mean BIA fat mass (kg)** | 23.6 (9.5) | 24.3 (10.8) |
| **Nonsmokers (%)** | 56.7 | 60.3 |

*Unweighted values.
*Weighted values.
*Sum of subscapular and triceps.
*Bioelectrical impedance analysis collected only from 1999 to 2004 in NHANES.

Mean values represent 2,995 Mexican Americans who completed this measure. BIA, bioelectrical impedance analysis; WHtR, waist to height ratio.
Nonlinearity and model fit statistics. AIC values for both the linear and quadratic models are presented in Supporting Information Tables S1–S2. For all-cause mortality, the AIC values were not markedly different between the linear and quadratic models; however, values were lower for the linear models for all body composition predictors except percent body fat. For cardiovascular-related mortality, the AIC values for the linear models were better for most predictors except sum of skinfolds. Similarly, for diabetes-related...
TABLE 2 Hazard ratios (HR) and 95% CIs for all-cause mortality by body composition measure in 5-unit increments for Mexican American adults in NHANES III and NHANES 1999-2010

| Body Composition Measure                      | Reference Values | No. of Events | HR (95% CI) | No. of Events | HR (95% CI) | No. of Events | HR (95% CI) |
|-----------------------------------------------|------------------|---------------|-------------|---------------|-------------|---------------|-------------|
| BMI (per 5 kg/m²)                             | 25.0 kg/m²       | 1,423         | 1.04 (0.96-1.11) | 109           | 1.10 (0.88-1.36) | 107           | 1.23 (0.99-1.52) |
| Waist circumference (per 5 cm)                | 87.4 cm          | 1,423         | 1.04 (1.01-1.07) | 109           | 1.05 (0.97-1.15) | 107           | 1.10 (0.99-1.22) |
| WHtR (per 0.05)                               | 0.53             | 1,423         | 1.08 (1.03-1.14) | 109           | 1.09 (0.96-1.25) | 107           | 1.26 (1.07-1.49) |
| Sum of skinfolds (per 5 mm)                   | 29.5 mm          | 1,423         | 0.97 (0.94-1.00) | 109           | 0.95 (0.86-1.06) | 107           | 1.00 (0.88-1.15) |
| Percent body fat (per 5%)                     | 25.7%            | 1,423         | 1.06 (0.96-1.17) | 109           | 0.91 (0.70-1.18) | 107           | 1.20 (0.96-1.52) |
| Lean mass (per 5 kg)                          | 43.0 kg          | 1,423         | 0.99 (0.94-1.04) | 109           | 1.21 (1.00-1.47) | 107           | 0.92 (0.69-1.23) |
| Fat mass (per 5 kg)                           | 18.0 kg          | 1,423         | 1.03 (0.97-1.09) | 109           | 1.03 (0.84-1.27) | 107           | 1.05 (0.86-1.28) |

Models adjusted for age, gender, and smoking status. Separate models estimated for each body composition measure. Bolded text indicates significance at P<0.05. WHtR, waist to height ratio.

Discussion

WHtR and waist circumference associated with a slight increased risk of all-cause mortality in Mexican Americans in NHANES III and NHANES 1999-2010 after controlling for age, gender, and smoking status. We found no association with all-cause mortality for lean mass or any of the other adiposity measures; however, we did find associations between body composition measures and cardiovascular-related mortality in Mexican American women in our stratified analysis. We also found that increases in WHtR associated with an increased risk of diabetes-related death overall and in women. Moreover, we found that including a nonlinear term for each body composition model for each data set did not alter our findings.

Our overall and female-specific findings of weak associations between increases in waist circumference and WHtR and all-cause mortality in Mexican Americans parallel those of Koster et al. (24), who examined the association between waist circumference and mortality in white, black, and Hispanic adults aged 50 to 71 years in the NIH-AARP Diet and Health Study. Using standard World Health Organization cut points, they observed a significant association with risk of death in Hispanic males with waist circumference >102 cm (HR: 1.38; 95% CI: 1.04-1.82) and Hispanic females with waist circumference >88 cm (HR: 1.74; 95% CI: 1.08-2.08). In contrast, our study provides estimates of a larger sample of Hispanics not limited to an older age range. Our findings are also similar to Flegal and Graubard’s (19) results using a heterogeneous population from NHANES III.

Additional studies have found associations between waist circumference and WHtR and mortality in women (25), black women (26), non-Hispanic men and women (24), and heterogeneous samples (27). Kahn et al. (27) examined different measures of adiposity in a sample from NHANES III and found that waist and WHtR associated with mortality in models adjusted for age, education, ancestry (white, black, and Mexican American), and smoking. For the associations between waist circumference and mortality, males had HR of 1.27 (95% CI: 1.08-1.51) and females had HR of 1.47 (95% CI: 1.29-1.67). For WHtR, males exhibited a 33% increased risk of death per standard deviation (SD) change in ratio, while females exhibited a 45% increased risk of mortality. Furthermore, Katzmarzyk et al. (28) found that waist circumference and WHtR associated with mortality in adjusted models for white and black participants in a longitudinal study of white and black men and women aged 18 to 89 years.

The lack of an association between other adiposity measures and all-cause mortality in this sample of Mexican American adults is similar to previous findings in other ethnic populations examined using NHANES data. For instance, Navaneethan et al. (29) did not find associations between percent body fat and mortality in NHANES 1999-2004. Moreover, while the results of this analysis, using more precise measures of adiposity and lean mass, confirm previous findings of an absence of a strong association between obesity (measured through BMI) and mortality in Hispanics (2,3), they are in contrast to recent work from our group that found an
increased risk of death in Mexican Americans with BMI ≥ 35 at the time of study participation and who reported a maximum lifetime BMI ≥ 35 (HR: 1.52; 95% CI 1.10-2.10) (30).

WHtR associated with an increased risk of diabetes-related death for Mexican Americans and specifically in Mexican American women. To our knowledge, this is the first study to examine the association between different body composition measures and diabetes-related mortality specifically in Mexican Americans. Our results are again similar to a recent study from our group that found that Mexican Americans in NHANES with maximum lifetime BMI ≥ 30 (but who lost weight over time) were at an increased risk of diabetes-related death (30). Furthermore, there is evidence that adults with BMI ≥ 35 in general are at a significantly increased risk of diabetes-related death (31). Considering that Hispanics have an increased risk of diabetes-related death overall compared with non-Hispanics (32), these results are cause for concern because obesity, particularly abdominal fat, may further increase the risk of diabetes-related deaths in Mexican American adults.

In the gender-stratified analysis, while we did not find evidence of an association between body composition and increased risk of cardiovascular-related deaths in Mexican American men, we did find protective associations in BMI, percent body fat, skinfolds, and fat mass. These results are similar to previous findings that individuals with overweight (i.e., BMI 25.0-29.9) had decreased all-cause mortality.
mortality among older Hispanics (2) and decreased CVD-related mortality in the general population (33), as well as in older individuals (34) and other nonwhite populations (35). Moreover, similar findings have been reported in individuals with known CVD (36,37), and there is evidence that Hispanics have lower rates of CVD mortality (38). Although we did not limit our CVD model to individuals with known CVD, individuals with CVD in our cohort may be influencing this association. Further investigation of these protective associations in Mexican American men is warranted. Conversely, we found significant associations between increases in BMI, waist circumference, and WHtR and cardiovascular mortality in Mexican American women, which are in line with previous studies in the general population (19,39).

Interestingly, we found that an increase in lean mass was associated with increased risk of CVD-related mortality in Mexican American females. This is in contrast to other similar studies that have found increases in lean mass to be protective. There is some evidence that lean individuals with hypertension have an increased risk of CVD mortality (40,41), and not adjusting for individuals with CVD-related chronic conditions in the current analysis may have affected the estimates. Additionally, estrogen, produced by fat cells (42), has been shown to be protective against CVD in women (43). Females with increases in lean mass may have decreases in fat mass, resulting in less protection against CVD. We also observed that increases in lean mass trended toward an increased risk of diabetes death in men. Our findings are similar to those discussed by George et al. (44), who found that men with “lean diabetes” have increases in overall mortality compared with men with obesity and diabetes. Lastly, the associations between lean mass and mortality may be different in this ethnic population, as seen in the BMI–mortality associations previously published (2,3), warranting further investigations.

Although the main aim of these analyses was to estimate associations between adiposity measures and mortality in Mexican Americans, previous investigations have sought to understand whether different measures of adiposity better predict mortality than does BMI (6,19,24,28). As an extension of this analysis, the body composition models (1-unit increment) were compared with a model with BMI by calculating a generalized $R^2$. Although it is not a direct measure of the amount of variance explained in the model, the value of $R^2$ increases when the predictors are strongly associated to the outcome. According to a simulation study by O’Quigley et al. (21), adjusting the Cox and Snell (22) formulas to account for the number of failures (deaths in our case) provided a stronger indicator of explained randomness in nonlinear models. Using this statistic as a crude way of comparing the models, we

### Table 3: Hazard ratios (HR) and 95% CIs for mortality by body composition measure in 5-unit increments for Mexican American adults in NHANES III and NHANES 1999-2010 by gender

| Body composition measure       | Reference values | No. of events | All-cause mortality (HR 95% CI) | No. of events | Cardiovascular-related mortality (HR 95% CI) | No. of events | Diabetes-related mortality (HR 95% CI) |
|--------------------------------|------------------|---------------|--------------------------------|---------------|-------------------------------------------|---------------|--------------------------------------|
| **Males**                      |                  |               |                                |               |                                          |               |                                      |
| BMI (per 5 kg/m²)              | 25.0 kg/m²       | 818           | 0.99 (0.88-1.10)               | 60            | 0.69 (0.48-0.98)                          | 52            | 1.35 (0.90-2.01)                      |
| Waist circumference (per 5 cm) | 89.0 cm          | 818           | 1.02 (0.98-1.06)               | 60            | 0.94 (0.82-1.07)                          | 52            | 1.12 (0.96-1.31)                      |
| WHtR (per 0.05)                | 0.53             | 818           | 1.05 (0.97-1.12)               | 60            | 0.84 (0.66-1.06)                          | 52            | 1.26 (0.96-1.66)                      |
| Sum of skinfolds (per 5 mm)    | 25.6 mm          | 818           | 0.96 (0.92-1.00)               | 60            | 0.79 (0.66-0.95)                          | 52            | 1.14 (0.97-1.34)                      |
| Percent body fat (per 5%)      | 22.5%            | 818           | 1.02 (0.91-1.14)               | 60            | 0.70 (0.53-0.93)                          | 52            | 1.17 (0.78-1.76)                      |
| Lean mass (per 5 kg)           | 52.2 kg          | 818           | 0.99 (0.93-1.06)               | 60            | 1.05 (0.82-1.33)                          | 52            | 1.07 (0.84-1.36)                      |
| Fat mass (per 5 kg)            | 15.8 kg          | 818           | 1.02 (0.94-1.10)               | 60            | 0.75 (0.58-0.97)                          | 52            | 1.19 (0.87-1.63)                      |
| **Females**                    |                  |               |                                |               |                                          |               |                                      |
| BMI (per 5 kg/m²)              | 25.0 kg/m²       | 605           | 1.08 (0.99-1.18)               | 49            | 1.37 (1.11-1.69)                          | 55            | 1.15 (0.94-1.42)                      |
| Waist circumference (per 5 cm) | 84.9 cm          | 605           | 1.06 (1.01-1.10)               | 49            | 1.15 (1.05-1.26)                          | 55            | 1.08 (0.97-1.21)                      |
| WHtR (per 0.05)                | 0.54             | 605           | 1.11 (1.04-1.18)               | 49            | 1.26 (1.10-1.44)                          | 55            | 1.24 (1.05-1.48)                      |
| Sum of skinfolds (per 5 mm)    | 38.8 mm          | 605           | 0.99 (0.95-1.03)               | 49            | 1.10 (0.95-1.27)                          | 55            | 0.91 (0.80-1.03)                      |
| Percent body fat (per 5%)      | 35.8%            | 605           | 1.11 (0.98-1.25)               | 49            | 1.13 (0.78-1.63)                          | 55            | 1.22 (0.89-1.69)                      |
| Lean mass (per 5 kg)           | 38.0 kg          | 605           | 0.97 (0.88-1.06)               | 49            | 1.58 (1.21-2.08)                          | 55            | 0.61 (0.32-1.17)                      |
| Fat mass (per 5 kg)            | 21.8 kg          | 605           | 1.04 (0.98-1.10)               | 49            | 1.18 (0.96-1.46)                          | 55            | 0.97 (0.77-1.21)                      |

Models adjusted for age and smoking status. Separate models estimated for each body composition measure. Bolded text indicates significance at $P<0.05$. WHtR, waist to height ratio.
found that most body composition measures had slightly higher R² values than BMI, particularly in the all-cause mortality model, indicating that these adiposity measures may have better predictive ability than BMI when estimating the obesity-mortality association among Mexican Americans. This is consistent with previous studies (6,24). Our results also appear to be similar to those of Flegal and Graubard (19), who found that, in NHANES III, anthropometric measures of adiposity (i.e., waist circumference, hip circumference, sum of skinfolds and arm circumferences), ratio measures of adiposity (WHIR), and percent body fat estimated from BIA were slightly associated with mortality but did not provide strikingly different results compared with the association observed between BMI and mortality.

It is important to acknowledge the limitations of these analyses. First, a limitation of all observational studies is that they show associations (or lack thereof) that may not necessarily indicate causation (or lack of causation). Second, our use of a generalized R² to compare models is a crude measurement, and the predictive ability of each model was not statistically compared with other models; rigorous analysis to compare the predictive ability of these models of adiposity (such as conducting sensitivity and specificity analyses) with BMI are warranted to understand which models are superior in Mexican American samples. Third, we had to limit the models estimating percent body fat and fat and lean mass via BIA to NHANES III and NHANES 1999-2004, which did not allow us to include an additional 6 years of data for more precise estimates. Because we combined NHANES III and NHANES 1999-2010 for analysis, we were limited to using BIA for body composition measures, as body composition was not assessed using DXA in NHANES III. Moreover, DXA is more accurate than BIA in measuring body composition, and estimates should be interpreted with this limitation in mind (45). Fourth, NHANES 1999-2010 did not collect hip measurements, precluding us from looking at the association between waist to hip ratios and mortality. Previous studies (19,25) have indicated associations between waist to hip ratio and mortality in other populations and would be useful to examine in a Hispanic population. Fifth, we did not adjust for other potential confounders that may influence the association between obesity and mortality, such as alcohol consumption, physical activity, and socioeconomic status, in order to preserve power. Sixth, although we used the largest set of available data involving Hispanic populations, there were relatively few deaths from CVD and diabetes. As such, the reliability of these estimates should be interpreted with caution. Lastly, we did not account for systematic measurement error in the various adiposity measures, and thus risk estimates may be an underestimate of the actual risk (i.e., bring the results toward the null); interpretation of estimates should keep this limitation in mind.

Strengths of this study include that this analysis is the first to examine specific body composition measures in relation to all-cause and cardiovascular- and diabetes-related mortality in Mexican American adults. In addition, this analysis used a large sample size, enabling the ability to yield precise estimates of the longitudinal association between measures of adiposity and mortality in this population. Furthermore, this analysis used nationally representative data and incorporated sampling weights to produce population estimates. Moreover, we found evidence that confirms previous findings from our group that obesity associates with an increased risk of diabetes-related death in a Hispanic population.

**Conclusion**

To our knowledge, this is the first investigation of the association between body composition measures and mortality in a large, nationally representative cohort of US-residing Mexican Americans. Overall, we found only three modest associations between indices of body composition and all-cause and diabetes-related mortality. This suggests that obesity, whether assayed via BMI or measures of body composition, may not associate as strongly with mortality among Mexican Americans as it does in other racial or ethnic groups. Further studies to understand the reasons for this are warranted.

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