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The Association between Muscle Weakness and Incident Diabetes in Older Mexican Americans

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Abstract

Objectives—A natural decline of muscle strength occurs during the aging process; however, preserving muscle strength may lower the rate of many preventable diseases such as diabetes, especially in higher risk populations. The purpose of this study was to examine the sex-specific association between muscle weakness and incident diabetes in older Mexican Americans.

Design—Observational, longitudinal study.

Setting—Urban and rural households in the Southwestern United States.

Participants—A subsample of 1,903 Mexican Americans aged at least 65 years without diabetes at baseline were followed for 19 years.

Measurements—Muscle weakness was assessed with a hand-held dynamometer and was normalized to body weight (normalized grip strength (NGS)). Male and female participants were categorized as weak if their NGS was ≤0.46 and ≤0.30, respectively. Sex-stratified Cox proportional hazard regression models were used to determine the association between muscle weakness and incident diabetes (self-reported) when using age as an entry variable and after adjusting for education, employment status, instrumental activities of daily living disability, interview language, marital status, and obesity. A sensitivity analysis was performed to account for influential outliers for the outcome variable (incident diabetes) and the model was re-run.

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Results—The hazard ratio for incident diabetes was 1.05 (95% confidence intervals (CI): 1.02–1.09; p<0.001) in weak vs. not-weak males and 1.38 (CI: 1.35–1.41; p<0.001) in weak vs. not-weak females, after adjusting for relevant covariates.

Conclusions—Muscle weakness was associated with an increased rate of diabetes in older Mexican American males and females. Health professionals should encourage activities that preserve muscle strength, thereby preventing the incidence of diabetes in older Mexican Americans.

Keywords

Aging; Handgrip strength; Preventative medicine; Obesity

Obesity prevalence and life expectancy have steadily increased worldwide, engendering two of today's greatest public health burdens, the obesity epidemic and an aging population.[1,2] Sarcopenic obesity, a convergence of these two problems, is a condition often seen in older adults, whereby age related changes in body composition leads to a decrease in fat free mass, relative to fat mass.[3] The simultaneous reduction of muscle mass and strength, increased abdominal fat mass, and age related declines in physical function pose many health risks across populations.[1,4,5] Consequently, older adults that are weak and obese are at greater risk for functional limitations and chronic cardiometabolic diseases such as diabetes.[6,7]

In the United States from 1990 to 2010, there was more than a half-million years of life lost due to diabetes related-premature mortality, and about 35,900 more deaths attributed to diabetes alone, thus, diabetes remains a leading cause of death.[8] Globally, diabetes prevalence is projected to increase by over 200 million people between 2013 and 2035.[9] The current and future impact of diabetes highlights the need to continue identifying strategies to screen for diabetes risk while developing interventions that mitigate diabetes prevalence and diabetes related mortality. Participating in physical activities that preserve or improve muscle strength has been recognized as a strategy to prevent and treat diabetes across populations.[10] For example, previous cross-sectional investigations have identified that muscle weakness is associated with diabetes.[11–13] Furthermore, studies have determined that increases in hyperglycemia,[14] fat mass,[15] and diabetes prevalence[16] are associated with reduced muscle quality and weakness.

The lifetime risk of diabetes is elevated among Mexican Americans, a population projected to increase by nearly 115% between the years 2014 and 2060 in the United States.[17,18,32] Chronic hyperglycemia and obesity, two known predictors of diabetes, are associated with poor muscle strength and quality, respectively.[14,15] Obesity is 7.4% greater in Hispanic Americans aged at least 60 years, compared to the national average of that age group,[19] thus older Mexican Americans that are obese and weak may be at an elevated risk for diabetes. Therefore, the purposes of this study were to 1) determine the association between muscle weakness and incident diabetes among older Mexican American males and females, and 2) identify obesity prevalence among weak vs. not-weak male and female Mexican Americans.

METHODS

Participants

Data were used from the Hispanic Established Population for the Epidemiological Study of the Elderly (HEPESE), an ongoing study of non-institutionalized Mexican Americans aged at least 65 years living in Arizona, California, Colorado, New Mexico, and Texas. The HEPESE was modeled after other previous epidemiological studies of the elderly that were conducted in Connecticut, Iowa, Massachusetts, and North Carolina.[20] As previously described,[21] the HEPESE used an area probability sampling procedure to ensure representativeness of the older Mexican American population in the Southwestern region of the United States. Sample weights are provided to account for the sampling method and they were used in all analyses. These weights compensate for the differential probability selection that was applied during data collection. HEPESE participants represent about 500,000 Mexican Americans aged at least 65 years living in participating states as a result of weighting the dataset. Starting in 1993–1994 (Wave 1), 3,050 older Mexican Americans participated in interviews and limited medical assessments (2,873 in person and 177 by proxy) with an 83.0% response rate, which is comparable to previous epidemiological studies of the elderly.[20] Baseline data were followed up in Waves: 2) 1995–1996 (n=2,438), 3) 1998–1999 (n=1,980), 4) 2000–2001 (n=1,682), 5) 2004–2005 (n=1,167), 6) 2006–2007 (n=921), 7) 2010–2011 (n=659), and 8) 2012–2013 (n=452). New participants from Wave 5 (n=902), Wave 6 (n=621), Wave 7 (n=419), and Wave 8 (n=292) that did not participate in baseline measures were excluded. The HEPESE protocols were approved by the University of Texas Medical Branch Institutional Review Board and informed consent was provided by participants.

Measures

Anthropometric Characteristics—Body weight and height was collected in the participant's home using similar methods as other epidemiological studies of the elderly. A Metro 9800 scale (Metro Scale & Systems Inc., Fort Myers, FL) was used to determine body weight and height was measured with a tape that participants stood next to against a wall. Body mass index (BMI) was calculated as body weight in kilograms (kg) divided by height in meters-squared.

Exposure Variable—Muscle strength was measured with a hand-held dynamometer (Jamar Hydraulic Dynamometer; J.A. Corp), as previously described in detail.[22,23] A trained interviewer explained and demonstrated the protocol to each participant, then adjusted the grip size of the dynamometer to each participant's hand size, and asked participants to perform a practice trial. While seated, participants performed the test with their dominant hand, exhaling while squeezing. During the test, interviewers verbally encouraged participants to squeeze the dynamometer with maximal effort. Two trials were performed, and the higher of the two measurements were included in analyses. A hand-held dynamometer has been shown to be a reliable and valid instrument for measuring muscle weakness in older adults.[22] Handgrip strength was normalized to body weight (normalized grip strength (NGS)) in order to account for the proportion of strength relative to body weight *(Grip strength (kg) / Body weight (kg))*.

For males, participants with a NGS ≤0.46 were categorized as weak; whereas, participants with a NGS >0.46 were categorized as not-weak. Among females, participants with a NGS ≤0.30 were classified as weak, while participants with a NGS of >0.30 were classified as not-weak. These NGS cut points were used from a previous investigation that studied a population that was similar in age and ethnicity.[11] Handgrip strength was adjusted to the corresponding body weight ascertained at baseline testing for each participant.

Covariates—Baseline, self-reported sociodemographic variables were included: education level, employment status, and marital status. Measures of instrumental activities of daily living (IADL) disability, interview language, and obesity were also included. A modified version of the Older Americans' Resources and Services IADL scale was used to assess IADL disability.[24]

Outcome Variable—The primary outcome variable of interest was incident diabetes. Participants that self-reported that a doctor told them they have diabetes were classified as having diabetes. The time variable was the age at which participants responded affirmatively to having diabetes. In the event that a participant was re-interviewed, but their age was missing for a particular wave, age was imputed by adding the median difference in age between the current wave and the previous wave for the cohort (1 year for Wave 2; 4 years for Wave 3; 3 years for Wave 4; 4 years for Wave 5; 2 years for Wave 6; 3 years for Wave 7; and 3 years for Wave 8).

Censoring and Truncation Mechanisms—Since participants had to be at least 65 years of age to be included in the HEPESE and participants entered the study at different ages, data were left truncated. Participants with prevalent diabetes at baseline were considered left-censored and removed from analyses because the present investigation was addressing the incidence of diabetes among older Mexican Americans. Right censoring occurred if participants did not have diabetes at the end of follow-up, were lost to follow-up, or died before getting diabetes.

Statistical Analysis

All statistical analyses were performed using SAS 9.4 software (SAS Institute; Cary, NC). Independent t-tests (continuous characteristics) and chi-squared tests (categorical characteristics) were conducted to examine baseline differences between the descriptive characteristics of the participants by sex. Thereafter, separate two-sample t-tests and chi-squared tests were conducted to identify differences between the baseline characteristics for weak vs. not-weak males and weak vs. not-weak females.

The time to diabetes was compared based on muscle weakness for weak vs. not-weak males and females. Sex-stratified Cox proportional hazards regression models were used to examine the association between weakness and incident diabetes after adjusting for education (highest grade of education completed), employment status (employed, not employed), IADL disability (has an IADL disability, no IADL disability), language of interview (English or Spanish language), marital status (married, not married), and obesity

(BMI ≥30 kg/m^2, BMI <30.0 kg/m^2). The participant's age at baseline was used as the entry variable.

A sensitivity analysis was performed to account for potentially influential outliers. First, outliers in the outcome variable were identified using deviance residuals. Observations with residuals greater than 2.5 were considered to be influential and were thereby removed.[25] The model was then re-run without those outliers to determine whether estimates changed. If an absolute percent change of more than 10% in the hazard ratios were identified, the results of the model that underwent the sensitivity analysis would be presented.[26]

Another sensitivity analysis was performed that considered the effect of missing NGS data. First, all participants with missing NGS were categorized as weak and the model was run, then the estimates were compared to the model with missing NGS excluded. Next, those with missing NGS were categorized as not-weak and the estimates were again compared to the original model. An absolute percent change of more than 10% in the hazard ratios was determined *a priori* to indicate if the effect of missing data was significant.[26] Analyses were performed separately for males and females. An alpha level of 0.05 was used for all analyses.

RESULTS

At baseline (Wave 1), there were 3,050 participants. Of these, 845 participants had prevalent diabetes and were excluded from subsequent analyses. An additional 302 participants were excluded because they had missing data for NGS. Participants with missing NGS had a lower percentage of employment (2.7% vs. 6.8%; p=0.01), obesity (8.6% vs. 28.2%; p<0.001), and a higher percentage of IADL disability (71.4% vs. 47.5%; p<0.001) compared to participants without missing NGS. After exclusions, data from 1,903 participants were included in analyses and their descriptive characteristics are presented in Table 1.

Weak males and females had greater BMIs, higher proportions of IADL disability, and had a higher prevalence of obesity than males and females that were not-weak (p<0.05) (Table 2). Moreover, a lower percentage of weak males and females were employed compared to males and females that were not-weak (p<0.05). Weak males had less education than non-weak males; whereas, fewer weak females were married than females that were not-weak (p<0.05).

Table 3 shows the sex-stratified, fully-adjusted Cox regression models used to examine the time to diabetes diagnosis based on muscle weakness. Table 4 presents the results of the sensitivity analysis for the Cox regression models after removing 237 and 283 potentially influential outliers for males and females, respectively. The sensitivity analysis revealed a 13.9% change in hazard ratios for males and a 11.3% change in females, indicating that influential observations had a significant effect on the association between NGS and incident diabetes, thereby suggesting the results from the models that underwent the sensitivity analysis should be presented. Therefore, weak males (hazard ratio (HR) 1.05; 95% confidence intervals (CI): 1.02–1.09) and weak females (HR: 1.38; CI: 1.35–1.41) had a greater rate of diabetes than males and females that were not-weak after adjusting for relevant covariates.

The results of the second sensitivity analysis revealed that muscle weakness estimates did not have an absolute percent change of more than 10% when those with missing data for NGS were categorized as weak (Appendix 1) or not-weak (Appendix 2) for both sexes. Thus, missing NGS data did not have a significant impact on the association between NGS and incident diabetes.

DISCUSSION

The primary findings from this investigation demonstrated that muscle weakness was significantly associated with incident diabetes in older Mexican Americans. Specifically, weak males and females had a 5.0% and 38.0% higher hazard of incident diabetes, respectively. This investigation also determined that BMI and obesity prevalence were greater in weak males and females compared to their non-weak counterparts. These findings lend support to the importance of preserving muscle strength as a means of reducing the rate of developing diabetes.

This investigation extends the current body of literature by demonstrating that weak, older Mexican Americans had a higher rate of developing diabetes compared to their non-weak counterparts. A recent cross-sectional study found that for every 0.05 decrement in NGS, there was a 26% increase in adjusted odds for diabetes.[13] Our results also parallel those of previous HEPESE studies that have shown muscle weakness was associated with an increased risk for functional limitation and all-cause mortality in older Mexican Americans.[22,27] Compared to other ethnicities, Mexican Americans have the highest prevalence of prediabetes.[28] Another study utilizing HEPESE data determined that diabetes prevalence had increased, and no improvements in diabetes-related complications occurred from baseline to Wave 5.[16] These studies support the notion that the increased prevalence of diabetes in older Mexican Americans may be largely driven by accelerated weakness with advancing age.

Life expectancy in the United States has increased by 4.2 years in males and 1.9 years in females from 1990 to 2010.[29] Although females are still living longer than males, the more pronounced increase in life expectancy in males compared to females might be attributed to changes in BMI. From 2009–2010 to 2011–2012, males aged at least 20 years (age adjusted) had a 2% decrease in obesity prevalence; whereas, females had a 0.3% increase in obesity prevalence.[19,30] In Hispanic Americans aged at least 60 years, obesity prevalence was 7.4% greater than the overall average for the same age group. We found that BMI was higher in weak males and females compared to males and females that were not-weak. Furthermore, obesity prevalence was 18.3% greater in weak males (compared to non-weak males) and 20.6% greater in weak females (compared to non-weak females). This suggests that a higher proportion of older, weak Mexican Americans were obese, likely increasing the prevalence of sarcopenic obesity, a condition that exacerbates the incidence of preventable diseases such as diabetes.[31] Our results for BMI, obesity prevalence, and NGS in weak vs. non-weak males and females are all lower than the results of a recent cross-sectional investigation of older Mexicans,[11] suggesting that a person's country of residence may impact these, and other health factors.

This study has some limitations that should be noted. Although our results underscore the association between muscle weakness and incident diabetes in older Mexican Americans, these findings may not be generalizable to other Hispanic American populations. The assessment of diabetes was self-reported. This may have led to inconsistencies between reported diabetes diagnosis and the age diabetes was diagnosed. Thus, participant age at the wave in which they first reported that a physician told them they had diabetes was used as the time variable, in lieu of self-reported age of diagnosis. It should be noted the sensitivity analysis which removed influential outliers resulted in a change in the hazard ratios for weakness in both sexes; however, the results remained significant.

Despite these limitations, this investigation has a number of strengths. Data from this investigation followed participants for 19 years in order to examine the association between muscle weakness and incident diabetes. This investigation also studied Mexican Americans, the largest cohort of Hispanics in the United States. Considering the expected rise in prevalence among this subpopulation, combined with an increasingly aging population, the results of the present investigation have important implications on preventing diabetes in older Mexican Americans.

CONCLUSION

Weak Mexican American males and females had a higher incidence of diabetes compared to males and females that were not-weak. The prevalence of obesity was also greater in males and females categorized as weak compared to their non-weak counterparts. The association between lower baseline muscle weakness and incident diabetes over 19 years suggests older Mexican Americans may benefit from activities and behaviors that preserve muscle strength, thereby helping reduce the rate of diabetes in this population.

Acknowledgments

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Appendix 1. Sensitivity Analysis for Categorizing Missing Normalized Grip Strength as Weak in A) Males and B) Females

A.

	Hazard ratio	95% confidence intervals	p-value
Muscle weakness (reference: strong males)	1.15	1.12–1.19	<0.001
Education	1.04	1.03–1.05	<0.001
Employed (reference: not employed)	1.16	1.12–1.21	<0.001
IADL disability (reference: no IADL disability)	0.87	0.84–0.90	<0.001
Interview Language (reference: Spanish)	0.93	0.90–0.96	<0.001
Married (reference: not married)	1.02	0.99–1.06	0.252
Obese (reference: not obese)	1.19	1.15–1.22	<0.001

B.

	Hazard ratio	95% confidence intervals	p-value
Muscle weakness (reference: strong females)	1.33	1.30–1.35	<0.001
Education	0.99	0.98–0.99	<0.001
Employed (reference: not employed)	1.56	1.50–1.63	<0.001
IADL disability (reference: no IADL disability)	0.84	0.82–0.86	<0.001
Interview language (reference: Spanish)	0.87	0.84–0.89	<0.001
Married (reference: not married)	0.92	0.90–0.94	<0.001
Obese (reference: not obese)	1.76	1.73–1.80	<0.001

IADL, instrumental activities of daily living.

Appendix 2. Sensitivity Analysis for Categorizing Missing Normalized Grip Strength as Not-Weak in A) Males and B) Females

A.

	Hazard ratio	95% confidence intervals	p-value
Muscle weakness (reference: strong males)	1.24	1.20–1.28	<0.001
Education	1.04	1.04–1.05	<0.001
Employed (reference: not employed)	1.17	1.12–1.22	<0.001
IADL disability (reference: no IADL disability)	0.88	0.85–0.91	<0.001
Interview language (reference: Spanish)	0.92	0.89–0.95	<0.001
Married (reference: not married)	1.01	0.98–1.05	0.587
Obese (reference: not obese)	1.15	1.11–1.19	<0.001

B.

	Hazard ratio	95% confidence intervals	p-value
Muscle weakness (reference: strong females)	1.27	1.24–1.30	<0.001
Education	0.99	0.98–0.99	<0.001
Employed (reference: not employed)	1.51	1.45–1.57	<0.001
IADL disability (reference: no IADL disability)	0.87	0.85–0.89	<0.001
Interview language (reference: Spanish)	0.88	0.85–0.90	<0.001
Married (reference: not married)	0.90	0.88–0.92	<0.001
Obese (reference: not obese)	1.80	1.77–1.84	<0.001

IADL, instrumental activities of daily living.

Table 1

Baseline Descriptive Characteristics of the Participants.

	Overall (n=1,903)	Males (n=801)	Females (n=1,102)
Absolute grip strength (kg)	23.2(9.1)	29.1 (9.1)*	18.8 (6.2)
Age (years)	73.3 (6.5)	73.4 (6.5)	73.2 (6.4)
Body mass index (kg/m^2)	27.6 (5.2)	26.8 (4.3)*	28.2 (5.7)
Body weight (kg)	70. 6 (13.8)	75.4 (12.7)*	67.1 (13.5)
Employed full- or part-time (%)	6.8	8.8*	5.4
Height (cm)	160.1 (10.4)	167.8 (8.1)*	154.5 (8.1)
Highest grade of education completed	4.9 (3.9)	4.9 (4.0)	4.8 (3.8)
IADL disability (%)	7.5	37.1	57.9
Interview completed in English (%)	22.4	24.1	21.1
Married (%)	54.9	74.2*	40.8
Normalized grip strength	0.33 (0.12)	0.39 (0.12)*	0.28 (0.09)
Obese (%)	28.2	21.4*	33.2

IADL, instrumental activities of daily living.

Obesity was defined as a body mass index ≥30.0 kg/m^2. Results are presented as mean (standard deviation) or percentage as indicated.

*Significant difference between males and females ($p<0.05$).

Table 2

Descriptive Characteristics of the Participants Stratified by Sex and Normalized Grip Strength.

	Males		Females	
	NGS ≤0.46 (n=571)	NGS >0.46 (n=230)	NGS ≤0.30 (n=605)	NGS >0.30 (n=497)
Absolute grip strength (kg)	25.8 (8.0)*	37.4 (5.9)	15.2 (5.0)*	23.2 (4.6)
Age (years)	74.4 (6.6)*	71.0 (5.7)	74.2 (6.8)*	72.0 (5.7)
Body mass index (kg/m^2)	27.6 (4.2)*	24.8 (3.8)	29.5 (6.0)*	26.5 (4.7)
Body weight (kg)	77.5(12.7)*	70.1 (11.0)	70.6 (14.3)*	62.8 (11.1)
Employed full- or part-time (%)	7.4*	12.2	3.8*	7.2
Height (cm)	167.7 (7.9)	168.2 (8.6)	154.8 (8.1)	154.1 (8.0)
Highest grade of education completed	4.7 (3.9)*	5.4 (4.3)	4.6 (3.7)	5.0 (3.9)
IADL disability (%)	41.2*	27.1	63.3*	45.0
Interview completed in English (%)	23.3	26.1	20.8	21.5
Married (%)	72.9	77.4	37.2*	45.3
Normalized grip strength	0.33 (0.09)*	0.53 (0.07)	0.21 (0.05)*	0.37 (0.05)
Obese (%)	26.6*	8.3	42.5*	21.9

IADL, instrumental activities of daily living.

Obesity was defined a participant having a body mass index ≥30.0 kg/m^2; Results are presented as mean (standard deviation) or percentage as indicated.

*Significant difference within sexes, between weak (NGS ≤0.46 for males and ≤0.30 for females) and not-weak (NGS>0.46 for males and >0.30 for females) participants (p<0.05).

Table 3

Cox Proportional Hazard Regression for Baseline Variables and Diabetes in A) Males and B) Females.

A.

	Hazard ratio*	95% confidence intervals
Muscle weakness (reference: strong males)	1.22	1.18–1.26
Education	1.06	1.05–1.06
Employed (reference: not employed)	1.25	1.20–1.31
IADL disability (reference: no IADL disability)	0.81	0.78–0.84
Interview language (reference: Spanish)	0.88	0.85–0.91
Married (reference: not married)	0.88	0.85–0.91
Obese (reference: not obese)	1.16	1.12–1.20

B.

	Hazard ratio*	95% confidence intervals
Muscle weakness (reference: strong females)	1.24	1.21–1.27
Education	0.99	0.98–0.99
Employed (reference: not employed)	1.51	1.49–1.58
IADL disability (reference: no IADL disability)	0.74	0.73–0.76
Interview language (reference: Spanish)	0.91	0.89–0.94
Married (reference: not married)	0.76	0.74–0.78
Obese (reference: not obese)	1.77	1.73–1.81

IADL, instrumental activities of daily living.

* $p<0.001$ for all hazard ratios

Table 4

Sensitivity Analysis for Baseline Variables and Diabetes in A) Males and B) Females.

A.

	Hazard ratio*	**95% confidence intervals**
Muscle weakness (reference: strong males)	1.05	1.02–1.09
Education	1.07	1.07–1.08
Employed (reference: not employed)	1.36	1.30–1.42
IADL disability (reference: no IADL disability)	0.85	0.82–0.88
Interview language (reference: Spanish)	0.90	0.87–0.94
Married (reference: not married)	0.89	0.86–0.92
Obese (reference: not obese)	1.15	1.11–1.19

B.

	Hazard ratio*	**95% confidence intervals**
Muscle weakness (reference: strong females)	1.38	1.35–1.41
Education	0.99	0.99–1.00
Employed (reference: not employed)	0.72	0.70–0.73
IADL disability (reference: no IADL disability)	0.69	0.68–0.71
Interview language (reference: Spanish)	0.91	0.89–0.94
Married (reference: not married)	0.72	0.70–0.73
Obese (reference: not obese)	1.71	1.69–1.75

IADL, instrumental activities of daily living.

* $p<0.001$ for all hazard ratios