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Original Study

Muscle Weakness Is Associated With Diabetes in Older Mexicans: The Mexican Health and Aging Study

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ABSTRACT

Background: The risk of cardiovascular problems due to diabetes mellitus is highest among older Mexicans, and yet what remains to be determined is the association between muscle weakness and diabetes in this population. Therefore, the purpose of this study was to determine the association between muscle strength and diabetes among Mexican adults greater than 50 years of age.
Design: Cross-sectional.
Setting: National sample of households in both urban and rural areas.
Participants: A subsample of 1841 individuals aged 50 years and older was included from the 2012 Mexican Health and Aging Study.
Measurements: Strength was assessed using a hand-held dynamometer, and the single largest reading from either hand was normalized to body mass (normalized grip strength [NGS]). Conditional inference tree analyses were used to identify sex-specific NGS weakness thresholds. Linear regression was used to examine the association between NGS and HbA1c, and logistic regression was used to assess the association between weakness and risk of diabetes (HbA1c $\geq$ 6.5% [$\geq$48 mmol/mol]), after controlling for age, sex, and waist circumference.
Results: NGS was inversely associated with HbA1c ($\beta = -1.56$; $P < .001$). Optimal sex-specific NGS weakness thresholds to detect diabetes were $\leq$0.46 and $\leq$0.30 for men and women, respectively. Weakness was associated with significantly increased odds of diabetes (odds ratio, 1.69; 95% confidence interval, 1.37-2.10), even after adjusting for age, sex, and waist circumference.
Conclusions: NGS was robustly associated with diabetes and other cardiometabolic risk factors in older Mexicans. This simple screen may serve as a valuable tool to identify adults that are at risk for negative health consequences or early mortality and who might benefit from lifestyle interventions to reduce risk.

Diabetes is a leading cause of mortality that is estimated to affect more than 400 million adults globally,[1] particularly in low- and middle-income countries where more than 80% of diabetes deaths occur.[2] For example, in Mexico the lifetime risk of diagnosed diabetes is projected to reach 50% by 2050,[3] and there is also a high prevalence of impaired glucose tolerance[4] and undiagnosed or uncontrolled

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diabetes.[5] From 1970 to 2010, Mexican mortality fell by twofold for individuals aged >50 years (from 33% to 17%), and this has been attributed to expanded health care infrastructure and access in poorer states.[6] Older adults, however, are at increased risk for chronic cardiometabolic diseases such as diabetes, a known driver of both years lived with a disability and disability-adjusted life years in Mexico.[7] An age-related decline in physical function and deterioration in muscle morphology contribute to exaggerated risk of diabetes at the individual level; and yet, increases in the incidence of diagnosed diabetes, combined with declining mortality levels, have led to an acceleration of lifetime diabetes risk and more years spent with diabetes at the population level. Therefore, the aging Mexican population poses a substantial burden to the country's future health care system.

Early screening and promotion efforts for healthy aging among higher-risk populations are vital to mitigate the incidence of diabetes and other preventable comorbidities, thereby curtailing the escalating health care costs associated with chronic conditions. There has been an increase in the amount of evidence that highlights the role of muscular strength preservation as a protective factor for cardiometabolic health across populations. Recent investigations[8–10] have shown that low muscular strength is independently associated with increased odds of the metabolic syndrome and diabetes in adults, and that cut points or centiles[11] for low normalized strength may be used to predict increased risk. Moreover, longitudinal data have demonstrated that chronic hyperglycemia[12] and greater fat mass[13] (ie, two hallmark risk factors for diabetes) are associated with diminished muscle quality and weakness. There is also mounting evidence that indicates a robust inverse association between low strength and cardiometabolic risk clustering among children and adolescents,[14–16] thus reinforcing the need for early and improved clinical screening strategies across populations. Therefore, the purposes of this study were to examine the independent association between handgrip strength capacity and diabetes in a large sample of aging adults in Mexico and to identify potential sex-specific weakness thresholds for detection of diabetes.

Research Design and Methods

Study Population

The Mexican Health and Aging Study (MHAS) was designed to prospectively evaluate the impact of disease on the health, function, and mortality of adults over the age of 50 years in a national sample of households in both urban and rural areas of Mexico. The overall goal of the study is to examine the aging process, including the impact of disease and disability in a large representative panel of older Mexicans, as previously described in detail.[17,18] The MHAS study protocols and instruments were approved by the Institutional Review Board or Ethics Committee of the University of Texas Medical Branch, the Instituto Nacional de Estadistica y Geografia (INEGI) in Mexico, and the Instituto Nacional de Salud Publica (INSP) in Mexico.

Of the 15,723 participants who were interviewed in the 2012 MHAS (survey wave 3), a sub-sample of 2086 was selected in order to collect anthropometric measures, blood pressure readings, performance tests, and blood biomarkers. Of these, 1841 participants had (1) complete demographic and anthropometric data; (2) valid strength data from a handgrip dynamometer; and (3) the necessary blood samples obtained for non-fasting glycohemoglobin determination.

Anthropometric Factors

Each participant wore light clothing and no shoes while being weighed on a digital Toledo scale (Mettler-Toledo International, Inc., Columbus, OH). Height was measured using a fixed stadiometer. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Standard categories were applied to determine if each participant was normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), or obese ($\geq$30.0 kg/m^2).[19] Individuals with BMI $<$ 18.5 kg/m^2 were excluded (n = 15), due to the known association between underweight status and diabetes risk in older adults.[20] Waist circumference was measured to the nearest 0.1 cm at the level of the iliac crest and used in the analyses as a continuous variable.

Cardiometabolic Parameters

Participants were tested on routine cardiometabolic parameters. Resting systolic and diastolic blood pressures were measured twice with a mercury sphygmomanometer by trained staff. Non-fasting measures of total cholesterol, HDL cholesterol, thyroid-stimulating hormone, serum 25-hydroxyvitamin D, and C-reactive protein concentrations were also measured. Nonfasting serum measures of glycohemoglobin (%) were included as a diagnostic test for diabetes, which reflects average plasma glucose for the previous ~3 months. HbA1c was measured using A1cNow assay, a method that is National Glycohemoglobin Standardization Program certified. Participant diabetes status was based on elevated nonfasting HbA_{1c} ($\geq$6.5% [$\geq$48 mmol/mol]), which reflects uncontrolled diabetes.[21]

Exposure Variable

Grip Strength

Strength was assessed using a hydraulic handgrip dynamometer (Jamar Hydraulic Dynamometer, model 5030J1; JA Preston Corp., Clifton, NJ). A trained examiner explained and demonstrated the protocol to each participant, then adjusted the grip size of the dynamometer to the participant's dominant hand size, and asked him or her to squeeze the dynamometer for a practice trial. Thereafter, the participant was instructed to start the test with his or her dominant hand and was asked to squeeze the dynamometer with maximal effort, exhaling while squeezing. The test was then repeated with the opposite hand. Each hand was tested twice, alternating hands between trials with a 60-second rest between measurements on the same hand. The grip test was performed in the standing position unless the participant was physically limited. Participants were excluded from this component if they were unable to hold the dynamometer and perform strength testing with both hands. Participants who had surgery on either hand or wrist in the last 3 months were not tested on that particular hand. Because the link between muscle strength and both physical function and chronic health is mediated by the proportion of strength relative to body mass, grip strength was normalized (NGS) as strength per body mass: $(\mathit{Grip\ Strength}(kg)/\mathit{Body\ Mass}(kg))$.

Statistical Analysis

All statistical analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC) and R version 3.1.2 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive characteristics and cardiometabolic profiles are provided as means, standard errors, and percentages. Differences in these characteristics across strength categories were tested using linear and logistic regression for continuous and categorical variables respectively, after creating appropriate categories and dummy coding for each. A similar strategy was used to test differences for outcomes between men and women.

Threshold analyses

Conditional inference tree analyses were used to determine risk thresholds of NGS in differentiating the risk for diabetes among all