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Nhanes 1999-2018
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Higher Risk of Sarcopenia in Older Adults with Type 2 Diabetes: NHANES 1999–2018

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Keywords
Sarcopenia · Diabetes mellitus · Prevalence · Older adults · Trend

Abstract
Introduction: Recent studies suggested that sarcopenia may be a significant comorbidity of diabetes mellitus (DM). Nonetheless, studies with nationally representative data are scarce, and the changing trend of sarcopenia prevalence over time is largely unknown. Therefore, we aimed to estimate and compare the prevalence of sarcopenia in diabetic and nondiabetic US older population, and to explore the potential predictors of sarcopenia as well as the trend of sarcopenia prevalent in the past decades. Methods: Data were retrieved from the National Health and Nutrition Examination Survey (NHANES). Sarcopenia and DM were defined according to corresponding diagnosis criteria. Weighted prevalence was calculated and compared between diabetic and nondiabetic participants. The differences among age and ethnicity groups were explored. Results: A total of 6,381 US adults (>50 years) were involved. The overall prevalence of sarcopenia was 17.8% for US elders, and the prevalence was higher (27.9% vs. 15.7%) in those with diabetes ones than those without. Stepwise regression revealed that sarcopenia was significantly associated with DM (adjusted odds ratio = 1.37, 95% CI: 1.08–1.22; p < 0.05) after controlling for potential confounders including gender, age, ethnicity, educational level, BMI, and muscle strengthening activity. A slight fluctuation but overall increasing trend of sarcopenia prevalence was observed among diabetic elders, while no obvious changing trend was observed in their counterparts in recent decades. Conclusion: Diabetic US older adults face significantly higher risk of sarcopenia when compared with their nondiabetic counterparts. Gender, age, ethnicity, educational level, and obesity were important influencing factors of sarcopenia development.

Siyu Dai and Dingbo Shu contributed equally to this work.

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Introduction

Globally, the rising burden of diabetes mellitus (DM) is a substantial concern for health-care systems, with about 9% of worldwide population diagnosed with DM, 90% of whom had type 2 DM (T2DM) [1]. According to the updated worldwide data, the USA (21% of all older adults) ranked as the 2nd among countries with the highest numbers of older adults diagnosed with DM, and China (20% of all older adults) ranked as the 1st, and India (17% of all older adults) ranked as the 3rd [2]. Moreover, scholars emphasized that a large number of older individuals have undiagnosed DM in the USA [3]. Older people often regard fatigue and weight loss as a phenomenon of normal aging [4].

The concern has been increasingly raised that the prevalence of sarcopenia presented an increasing trend and may be a significant comorbidity of DM [5, 6]. It has also been reported that every 10% reduction in skeletal muscle loss can save about one billion dollars of US medical care costs per year, and the potential comorbidity of sarcopenia and DM can significantly increase the disease burden of elders [7]. Thus, it is of importance to recognize the prevalence of sarcopenia in diabetic individuals, as skeletal muscle is the largest post-prandial glucose consumption organ, while having proper skeletal muscle mass is the key in maintaining glycemic control [8]. DM combined with sarcopenia can increase the risk of physical weakness and double the risk of physical disability [9]. For instances, diabetic patients combined with sarcopenia tend to fall, while falling significantly increases the hospitalization rate and largely reduces the quality of life of the diabetic elders. Furthermore, the metabolic consequence of hyperglycemia is catabolism. Catabolism may lead to loss of muscle mass, decreased muscle function as well as aggravation of insulin resistance [6, 10].

Though clear awareness of the huge burden caused by comorbid conditions of DM and sarcopenia has been raised, related epidemiologic research that investigated the prevalence of sarcopenia among diabetic population is scarce. Previous studies recruited participants from single centers and were of limited sample size. Nationally representative studies are lacking. The National Health and Nutrition Examination Survey (NHANES) is designed to represent the US non-institutionalized population, and the data have been collected in cycles of every 2 years. Therefore, the current analyses were performed to estimate and compare the prevalence of sarcopenia in diabetic and nondiabetic US older adults based on the nationally representative data. Meanwhile, we aimed to explore the association between DM and sarcopenia with potential risk factors, as well as to explore the trends of the prevalence of sarcopenia over times.

Materials and Methods

Data Source and Study Participants

Data were retrieved from the NHANES, which is a nationwide survey study conducted in every 2 years using a multistage, stratified, clustered probability design in order to represent the US non-institutionalized population. Household interviews were administered by trained interviewers; self-reported information regarding demographics (age, gender, ethnicity, educational level, household income), medical condition, physical activities, alcohol use, and smoking status was collected [11]. Dietary interview and private health interview (including health status) were carried out in mobile examination centers (MECs) by trained MEC interviewers; anthropometric characteristics, blood samples, and dual-energy X-ray absorptiometry (DXA) were also acquired in MECs.

The included participants were divided into four age groups (50–59, 60–69, 70–79, and above 80 years) and five US ethnic groups [non-Hispanic whites (NH white), non-Hispanic blacks (NH black), Mexican Americans (MA), other Hispanics, and other races]. Body weight was measured by digital scale, and body height was measured by stadiometer [11]. Obesity is an important influential factor of sarcopenia, while body mass index (BMI) is the validated indicator for body fatness [12]. In our study, BMI was categorized into four groups (underweight: ≤18.5, healthy weight: 18.5–24.9, overweight: 25–29.9, and obesity ≥30) according to the standards by Centers of Disease Control and Prevention (CDC) of the USA [13]. Furthermore, patients with DM might be advised to restrict their diet; thus, dietary conditions may confound the direct association between sarcopenia and diabetes [14, 15]. Dietary intake of macronutrients (protein, carbohydrates, and fat) was measured by using recalled 24-h food diary, and energy adjustment for each macronutrient was used by dividing total calorie intake. According to the Dietary Guidelines for Americans, the acceptable macronutrient distribution range was used to classify each macronutrient intake into three categories [16]. Physical activity level and muscle strengthening activity (defined as “physical activities specifically designed to strength your muscle such as lifting weight, push-ups, or sit-ups”) as well as smoking status were retrieved from the data sections of demographics and questionnaires [17]. Alcohol use was classified into drinker and non-drinkers by using the dietary data.

Definition of DM

The participant was considered as diabetic if they met at least one of the following criteria: (1) self-reported doctor-diagnosed DM; (2) plasma HbA1c level ≥6.5%; (3) fasting plasma glucose level ≥126 mg/dL [18]. Previous diagnosis of DM was obtained from self-reported medical conditions. A fasting blood sample was collected by a phlebotomist to measure glycemic control (HbA1c) and plasma glucose levels in the morning following a minimum 8-h fast [11].

Dai/Shu/Meng/Chen/Wang/Liu/Xiao/Guo/Chen

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Spearman correlation was used to explore the association between sarcopenia prevalence via time was explored by using a line chart. For the exploration of variation tendency, the age groups (50–59, 60–69, 70–79, and above 80 years). Wald \( \chi^2 \) test was used for non-parametric data, and independent \( \chi^2 \) test was used for parametric data. Univariate and multivariate logistic regressions were performed to determine the association between sarcopenia status (yes/no) and DM status (yes/no). Potential covariates were selected referring to previous similar research, which included age, gender, ethnicity, educational level, dietary conditions, physical activity level, obesity, muscle strengthening activity, and the utilization of anti-DM medication. Both stepwise selection model and entry full model were used for regressions, in order to avoid potential over-adjustment and to test the robustness of the association between sarcopenia and DM.

Sarcopenia Prevalence Trend of 50–59 Years over the Past Years

For survey cycle 2005–2006, DXA was only performed on participants below 69 years; for the surveys between 2007 and 2010, DXA data on ALM were not available; for survey cycles after 2011, DXA was only performed on participants below 60 years. Therefore, only the 50–59 age group had the sarcopenia data from 1999 to 2018. For the exploration of variation tendency, the sarcopenia prevalence via time was explored by using a line chart. Spearman correlation was used to explore the association between the survey cycles and the sarcopenia prevalence.

Definition of Body Composition and Sarcopenia

DXA has been widely used to assess sarcopenia. DXA measures the lean mass of whole body, including the trunk and four limbs, of which skeletal muscle is the largest component. DXA scans were conducted on individuals of 8 years and older who were not pregnant. Participants of body height over 196 cm and body weight over 136 kg were excluded for DXA examination. Whole body DXA scans were obtained by using a QDR 4500A densitometer (Hologic, Inc., Bedford, MA). It has been found by Schoeller et al. that the QDR 4500A Hologic densitometers underestimate fat mass in adults; thus, in NHANES surveys the fat mass and lean soft tissue mass were calibrated without affecting total mass [11, 19]. All scans were sent to the University of California, San Francisco, for further process with standard protocols.

Appendicular lean mass (ALM) was calculated by summing up lean tissues (excluding bone) of the four limbs. The criteria for ALM-defined sarcopenia were partially adopted from the Foundation for the National Institutes of Health (FNHI) as ALM divided by BMI, and sarcopenia was defined as a binary variable if ALM/BMI is less than 0.789 for male and less than 0.512 for female [20]. Multiple imputations were carried out in our analyses to deal with missing data strictly followed by the NHANES analytical guidelines [19, 21].

Statistical Analyses

Sarcopenia Prevalence among Adults above 50 Years

DXA scans were performed for all participants aged above 50 years in the survey cycles of 1999–2000, 2001–2002, and 2003–2004, while later survey cycles set relatively low upper age limits for DXA scan participation. The data of the survey cycles of 1999–2004 were combined as suggested by NHANES analytic guidelines. Descriptive statistics were summarized for demographics, anthropometrics, sarcopenia, and diabetes-related characteristics. The prevalence of sarcopenia was calculated in total participants, diabetic and nondiabetic groups, and the four age groups (50–59, 60–69, 70–79, and above 80 years). Wald \( \chi^2 \) test was used for non-parametric data, and independent \( t \) test was used for parametric data. Univariate and multivariate logistic regressions were performed to determine the association between sarcopenia status (yes/no) and DM status (yes/no). Potential covariates were selected referring to previous similar research, which included age, gender, ethnicity, educational level, dietary conditions, physical activity level, obesity, muscle strengthening activity, and the utilization of anti-DM medication. Both stepwise selection model and entry full model were used for regressions, in order to avoid potential over-adjustment and to test the robustness of the association between sarcopenia and DM.

Sarcopenia Prevalence Trend of 50–59 Years over the Past Years

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Statistical Analyses with Sample Weights and Multiple Imputation

Sample weights were generated by NHANES in order to meet the population totals from the Census Bureau and to adjust for the differential probabilities of selection. All analyses were performed using the combined sample weights of 1999–2004 according to the analytical guidelines [11]. Survey package was used for statistical analysis to incorporate sample weights. Five DXA imputation datasets were generated by NHANES. Hmisc package was used for dataset import. Data related to DXA were calculated, respectively, by using each imputed dataset, including ALM, ALM/BMI, prevalence, and logistic regression. According to NHANES DXA technical documentation, the combined estimate of prevalence, odds ratios (OR), adjusted OR (AOR) were the mean values of five imputation datasets, while standard errors and 95% confidence intervals (95% CIs) were calculated based on variance within and between imputation variances [21]. A p value equal or smaller than 0.05 was regarded as statistically significant. All data were analyzed using R 4.0.3.

Results

Characteristics of the Study Participants

A total of 6381 US older adults (\( \geq 50 \) years) were included in the prevalence analyses (Table 1). Among all the participants, 17.6% (\( n = 1,401 \)) were DM patients. 42.6% of all the elders were in the age group of 50–59 years, 28.6% in the group of 60–69 years, 19.5% in the group of 70–79 years, while less of them (9.4%) were in the age group \( \geq 80 \) years. As for ethnicities, the majority of the study participants were NH white (78.9%), followed by NH black (8.7%), other Hispanic (4.6%), other races (4.2%), and MA (3.6%). 38.0% of the participants were overweight, and 32.9% were obese. For the dietary condition, the average total energy intake \( \pm SD \) was 1,906.4 \( \pm 817.5 \) kcal for all participants (male: 2,230.1 \( \pm 901.8 \) kcal, female: 1,631.0 \( \pm 616.5 \) kcal). The majority of (87.2%) the participants reported protein intake of 10–35%E; more than half of all the participants had carbohydrate intake as 45–65%E. It is noteworthy that 46.2% of the elders took fat as 20–35%E, and 42.5% of all the elders took fat as \( \geq 35\% \)E. As for physical activity level, most of the participants had a low to moderate activity levels.

Significant difference was observed between diabetic and nondiabetic participants regarding sarcopenia and DM-related characteristics (Table 2). The mean fasting plasma glucose level was 109.8 mg/dL (SD: 17.9 mg/dL), and the mean plasma HbA1c level was 5.7% (SD: 5.7%). Mean values of ALM and ALM/BMI for male were 25,094.2 g (SD: 4,298.1 g) and 0.897 (SD: 0.125), respectively, and for female 16,830.2 g (SD: 3,510.3 g) and 0.512 (SD: 0.097), respectively.
Table 1. Demographics of the study participants

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>%</th>
<th>SE</th>
</tr>
</thead>
<tbody>
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<td>Total</td>
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<td>NA</td>
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<tr>
<td>Gender</td>
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<td></td>
<td></td>
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<tr>
<td>Female</td>
<td>3,247</td>
<td>53.9</td>
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<tr>
<td>Male</td>
<td>3,134</td>
<td>46.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Age groups</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>50–59 years</td>
<td>1,723</td>
<td>42.6</td>
<td>2.2</td>
</tr>
<tr>
<td>60–69 years</td>
<td>2,091</td>
<td>28.6</td>
<td>1.5</td>
</tr>
<tr>
<td>70–79 years</td>
<td>1,533</td>
<td>19.5</td>
<td>0.9</td>
</tr>
<tr>
<td>≥80 years</td>
<td>1,034</td>
<td>9.4</td>
<td>0.7</td>
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<tr>
<td>Ethnicity</td>
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<td></td>
<td></td>
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<tr>
<td>MA</td>
<td>1,255</td>
<td>3.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>240</td>
<td>4.6</td>
<td>1.4</td>
</tr>
<tr>
<td>NH white</td>
<td>3,617</td>
<td>78.9</td>
<td>6.0</td>
</tr>
<tr>
<td>NH black</td>
<td>1,067</td>
<td>8.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Other races</td>
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<td>0.6</td>
</tr>
<tr>
<td>Household income</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$35,000 below</td>
<td>3,061</td>
<td>38.6</td>
<td>2.5</td>
</tr>
<tr>
<td>$35,000 to $65,000</td>
<td>1,372</td>
<td>25.6</td>
<td>1.8</td>
</tr>
<tr>
<td>$65,000 above</td>
<td>1,141</td>
<td>25.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Unclear</td>
<td>100</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Educational level</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Less than 9th grade</td>
<td>1,423</td>
<td>10.9</td>
<td>0.8</td>
</tr>
<tr>
<td>9–11th grade</td>
<td>1,029</td>
<td>14.1</td>
<td>1.0</td>
</tr>
<tr>
<td>High school grade</td>
<td>1,455</td>
<td>26.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Some college</td>
<td>1,371</td>
<td>25.8</td>
<td>1.6</td>
</tr>
<tr>
<td>College graduate or above</td>
<td>1,085</td>
<td>22.8</td>
<td>1.3</td>
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<tr>
<td>Unclear</td>
<td>17</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Alcohol use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinker</td>
<td>1,427</td>
<td>25.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Non-drinker</td>
<td>4,548</td>
<td>69.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Unclear</td>
<td>406</td>
<td>5.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every day</td>
<td>843</td>
<td>14.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Some days</td>
<td>124</td>
<td>1.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Not at all</td>
<td>2,462</td>
<td>38.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Muscle strengthening activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1,058</td>
<td>19.1</td>
<td>1.4</td>
</tr>
<tr>
<td>No</td>
<td>4,991</td>
<td>76.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Unable to do activity</td>
<td>327</td>
<td>4.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Unclear</td>
<td>4</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit during the day and do not walk about very much</td>
<td>1,833</td>
<td>27.23</td>
<td>1.49</td>
</tr>
<tr>
<td>Stand or walk about a lot during the day, but not have to carry or lift things very often</td>
<td>3,538</td>
<td>54.33</td>
<td>2.76</td>
</tr>
<tr>
<td>Lift light load or have to climb stairs or hills often</td>
<td>781</td>
<td>14.38</td>
<td>0.88</td>
</tr>
<tr>
<td>Do heavy work or carry heavy loads</td>
<td>215</td>
<td>3.85</td>
<td>0.39</td>
</tr>
<tr>
<td>Refused</td>
<td>2</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Do not know</td>
<td>11</td>
<td>0.18</td>
<td>0.07</td>
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<tr>
<td>BMI, kg/m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤18.5</td>
<td>73</td>
<td>1.1</td>
<td>0.2</td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>1,749</td>
<td>28.1</td>
<td>1.4</td>
</tr>
<tr>
<td>25–29.9</td>
<td>2,499</td>
<td>38.0</td>
<td>1.8</td>
</tr>
<tr>
<td>≥30 (Obesity)</td>
<td>2,060</td>
<td>32.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Total energy intake (kcal)a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1,906.4</td>
<td>NA</td>
<td>10.23</td>
</tr>
<tr>
<td>Male</td>
<td>2,230.1</td>
<td>NA</td>
<td>16.11</td>
</tr>
</tbody>
</table>
0.596 (SD: 0.088), respectively. ALM and ALM/BMI were significantly different between diabetic and nondiabetic participants ($p < 0.0001$). Imputation results of ALM and ALM/BMI are shown in online supplementary Tables 1 and 2 (for all online suppl. material, see www.karger.com/doi/10.1159/000530241).

**Prevalence of Sarcopenia and DM Status**

The overall sarcopenia prevalence of 17.6% was observed in participants aged above 50 years, and the prevalence was 27.9% versus 15.7% for diabetic and nondiabetic populations, respectively (Table 3). As for age-specific sarcopenia prevalence, the increased prevalence was observed in older age groups (Table 4; online suppl. Fig. 1). In all age groups, diabetic participants always presented significantly higher sarcopenia prevalence than their nondiabetic counterparts. Sarcopenia prevalence was also different among ethnicities, and the highest prevalence was observed in MA, followed by other Hispanic, NH white, and NH black (Table 4; online suppl. Fig. 2).

In order to explore the trend of sarcopenia prevalence, participants of 50–59 years of each survey cycle of 1999–2006 and 2011–2018 were selected. The prevalence was calculated (online suppl. Table 5). There were no significant changes of sarcopenia prevalence in total, diabetic, and nondiabetic participants. A slight fluctuation was observed in diabetic participants with an insignificant coefficient of 0.095 from Spearman correlation between survey cycles and the sarcopenia prevalence (online suppl. Table 6). The difference between diabetic and nondiabetic participants was significant in the past two decades (Fig. 1).

37.8% of the DM participants did not use any anti-DM medication. No significant difference was observed when comparing the sarcopenia prevalence between DM patients using and not using anti-DM medication, and no matter insulin/anti-diabetic pills were used solely or together (online suppl. Table 10). Moreover, the prevalence of sarcopenia among diabetic elders with anti-DM medication showed no significant difference when compared with DM patients without anti-DM medication. The imputed results of sarcopenia prevalence can be found in online supplementary Tables 3 and 4.

**Logistic Regression between DM and Sarcopenia Status**

Univariate and multivariate logistic regressions were performed among older adults (Table 5). According to our analyses, sarcopenia was statistically significant associated with DM in the univariate logistic regression (OR = 2.08, 95% CI: 1.75–2.48, $p$ value < 0.0001). After controlling for gender, age, ethnicity, educational level, BMI, and muscle strengthening activity, which were selected by stepwise selection model, the multivariate logistic regression revealed a solid association between sarcopenia and DM (AOR: 1.37, 95% CI: 1.08–1.72, $p$ value < 0.05).

---

**Table 1 (continued)**

<table>
<thead>
<tr>
<th>Total protein intake (%E)</th>
<th>N</th>
<th>%</th>
<th>SE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>431</td>
<td>7.2</td>
<td>0.5</td>
</tr>
<tr>
<td>10–35</td>
<td>5,523</td>
<td>87.2</td>
<td>4.1</td>
</tr>
<tr>
<td>≥35</td>
<td>21</td>
<td>0.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total carbohydrate intake (%E)</th>
<th>N</th>
<th>%</th>
<th>SE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;45</td>
<td>1,777</td>
<td>30.8</td>
<td>1.8</td>
</tr>
<tr>
<td>45–65</td>
<td>3,644</td>
<td>56.5</td>
<td>2.6</td>
</tr>
<tr>
<td>≥65</td>
<td>554</td>
<td>7.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total fat intake (%E)</th>
<th>N</th>
<th>%</th>
<th>SE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20%</td>
<td>412</td>
<td>5.9</td>
<td>0.5</td>
</tr>
<tr>
<td>20%–35%</td>
<td>3,086</td>
<td>46.2</td>
<td>1.9</td>
</tr>
<tr>
<td>≥35%</td>
<td>2,477</td>
<td>42.5</td>
<td>2.8</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>DM status</th>
<th>N</th>
<th>%</th>
<th>SE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetic elders</td>
<td>1,401</td>
<td>17.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Nondiabetic elders</td>
<td>4,980</td>
<td>82.4</td>
<td>3.6</td>
</tr>
</tbody>
</table>

*Presented as mean value and SE. N is the unweighted count of the participants. SE, standard error. Protein, carbohydrate, and fat intake was measured by the energy percentage of total calorie intake.
Demographics of gender, age, ethnicity, educational level were significantly associated with sarcopenia status in both univariate and multivariate logistic regressions. Male showed higher risk of sarcopenia than female after adjustment (AOR: 1.96, 95% CI: 1.70–2.26, p value <0.0001). NH white and NH black showed lower risk than MA. Higher education was associated with lower risk of sarcopenia. Of note, obese participants (BMI ≥30) faced about 6.12 (95% CI: 4.76–7.87, p value <0.0001) times of risk than populations with healthy weight, while muscle strengthening activity showed promoting effect against sarcopenia (AOR: 0.65, 95% CI: 0.50–0.84, p value <0.01). Physical activity level was significantly associated with lower risk of sarcopenia status in

Table 2. Sarcopenia and diabetes-related characteristics by diabetic conditions

<table>
<thead>
<tr>
<th></th>
<th>Total mean</th>
<th>SD</th>
<th>Diabetic mean</th>
<th>SD</th>
<th>Nondiabetic mean</th>
<th>SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waist circumference, cm</td>
<td>99.5</td>
<td>14</td>
<td>107.1</td>
<td>13.8</td>
<td>98</td>
<td>13.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>108.7</td>
<td>13.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>105.4</td>
<td>14.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p value b/w gender</td>
<td>&lt;0.0001</td>
<td></td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>28.4</td>
<td>10.1</td>
<td>30.9</td>
<td>10.1</td>
<td>27.9</td>
<td>10.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>28.2</td>
<td>7.6</td>
<td>30.3</td>
<td>7.8</td>
<td>28.7</td>
<td>7.5</td>
<td></td>
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<tr>
<td></td>
<td>28.6</td>
<td>6.8</td>
<td>31.6</td>
<td>6.7</td>
<td>28</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>p value b/w gender</td>
<td>&lt;0.05</td>
<td></td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fasting plasma glucose level, mg/dL</td>
<td>109.8</td>
<td>17.9</td>
<td>160.8</td>
<td>19.1</td>
<td>98.7</td>
<td>17.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>112.5</td>
<td>16.2</td>
<td>161.3</td>
<td>17.4</td>
<td>100.8</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>107.4</td>
<td>17.3</td>
<td>160.3</td>
<td>19.4</td>
<td>96.9</td>
<td>16.5</td>
<td></td>
</tr>
<tr>
<td>p value b/w gender</td>
<td>&lt;0.001</td>
<td></td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fasting plasma HbA1c level (%)</td>
<td>5.7</td>
<td>5.7</td>
<td>7.3</td>
<td>6.1</td>
<td>5.4</td>
<td>5.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>5.8</td>
<td>4.8</td>
<td>7.3</td>
<td>5.4</td>
<td>5.4</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.7</td>
<td>6.3</td>
<td>7.3</td>
<td>6.8</td>
<td>5.4</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>p value b/w gender</td>
<td>&lt;0.05</td>
<td></td>
<td>&lt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALMa, g</td>
<td>20,637</td>
<td>5,667.7</td>
<td>21,782.7</td>
<td>5,739.8</td>
<td>20,391.8</td>
<td>5,622.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>25,094.2</td>
<td>4,298.1</td>
<td>25,556.5</td>
<td>4,554.9</td>
<td>24,984.8</td>
<td>4,228.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16,830.2</td>
<td>3,510.3</td>
<td>18,007.7</td>
<td>4,081.5</td>
<td>16,600.3</td>
<td>3,340.2</td>
<td></td>
</tr>
<tr>
<td>p value b/w gender</td>
<td>&lt;0.0001</td>
<td></td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALM/BMIa</td>
<td>0.735</td>
<td>0.184</td>
<td>0.713</td>
<td>0.174</td>
<td>0.739</td>
<td>0.186</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>0.897</td>
<td>0.125</td>
<td>0.853</td>
<td>0.122</td>
<td>0.908</td>
<td>0.123</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.596</td>
<td>0.088</td>
<td>0.573</td>
<td>0.079</td>
<td>0.600</td>
<td>0.089</td>
<td></td>
</tr>
<tr>
<td>p value b/w gender</td>
<td>&lt;0.0001</td>
<td></td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p value is the results from independent t test between participants with and without diabetes; p value b/w gender is the results from independent t tests between male and female. NS, non-significant results with p value >0.05. SD was combined according to DXA technical documentation, and p values were summarized from five imputation DXA datasets followed by the NHANES guideline.

Table 3. The overall sarcopenia prevalence between diabetic and nondiabetic populations

<table>
<thead>
<tr>
<th></th>
<th>Total mean (%)</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
<th>Diabetic mean (%)</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
<th>Nondiabetic mean (%)</th>
<th>95% CI LL</th>
<th>95% CI UL</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.8</td>
<td>17.5</td>
<td>18.2</td>
<td>27.9</td>
<td>27.4</td>
<td>28.4</td>
<td>15.7</td>
<td>15.4</td>
<td>16.0</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

The difference was tested by Wald χ². 95% CIs were combined according to DXA technical documentation, and p value was summarized from five imputation DXA datasets followed by the NHANES guideline.
univariate logistic regression, but it was no longer significant after adjustment. Macronutrient intake was not significantly associated with sarcopenia status. Multiple models were built as to avoid the potential over-adjustment, and similar main results remained (online suppl. Tables 7–9).

### Discussion

The increasing global disease burden of sarcopenia and DM has been aggravated. Surveillance and management are of strong need as to improve active life quality and expectancy of older population. Nationally representative data have been rarely conducted and reported. Therefore, we explored the sarcopenia prevalence and its changes over time, and we also identified potential predictors which related to sarcopenia onset as well as progression which may contribute to the disease prevention and control. We found that diabetic US adults aged above 50 years presented vastly higher overall prevalence of sarcopenia than their nondiabetic counterparts (27.9% vs. 15.7%). And the prevalence of sarcopenia has been found highest in MA, followed by other Hispanics, NH white, and NH black. Slight overall increasing trend of the sarcopenia prevalence of diabetic populations was found in the last decades, while the prevalent condition remained stable for participants without DM. According to our multiple regressions, diabetic condition maintained robustly associated with sarcopenia status after Table 4. Sarcopenia prevalence between diabetic and nondiabetic populations by year groups and ethnicities

<table>
<thead>
<tr>
<th>Ethnicities</th>
<th>Total</th>
<th>Diabetic</th>
<th>Nondiabetic</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>95% CI</td>
<td>mean 95% CI</td>
<td>mean 95% CI</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>UL</td>
<td>LL</td>
<td>UL</td>
</tr>
<tr>
<td>50–59 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.8</td>
<td>10.5</td>
<td>11.2</td>
<td>23.3</td>
</tr>
<tr>
<td>MA</td>
<td>28.5</td>
<td>22.8</td>
<td>34.1</td>
<td>34.2</td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>17.8</td>
<td>8.0</td>
<td>27.6</td>
<td>18.1</td>
</tr>
<tr>
<td>NH white</td>
<td>9.8</td>
<td>9.3</td>
<td>10.3</td>
<td>27.5</td>
</tr>
<tr>
<td>NH black</td>
<td>2.7</td>
<td>2.1</td>
<td>3.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Other races</td>
<td>18.4</td>
<td>14.7</td>
<td>22.1</td>
<td>25.0</td>
</tr>
<tr>
<td>60–69 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17.3</td>
<td>17.0</td>
<td>17.6</td>
<td>27.2</td>
</tr>
<tr>
<td>MA</td>
<td>41.8</td>
<td>40.5</td>
<td>43.1</td>
<td>40.3</td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>28.4</td>
<td>21.4</td>
<td>35.3</td>
<td>32.9</td>
</tr>
<tr>
<td>NH white</td>
<td>16.7</td>
<td>16.3</td>
<td>17.0</td>
<td>29.2</td>
</tr>
<tr>
<td>NH black</td>
<td>3.8</td>
<td>3.7</td>
<td>3.9</td>
<td>8.4</td>
</tr>
<tr>
<td>Other races</td>
<td>24.8</td>
<td>24.5</td>
<td>25.2</td>
<td>28.6</td>
</tr>
<tr>
<td>70–79 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26.7</td>
<td>26.2</td>
<td>27.2</td>
<td>30.2</td>
</tr>
<tr>
<td>MA</td>
<td>48.1</td>
<td>46.6</td>
<td>49.6</td>
<td>52.2</td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>53.0</td>
<td>50.1</td>
<td>56.0</td>
<td>61.3</td>
</tr>
<tr>
<td>NH white</td>
<td>25.7</td>
<td>25.1</td>
<td>26.3</td>
<td>30.6</td>
</tr>
<tr>
<td>NH black</td>
<td>12.2</td>
<td>11.3</td>
<td>13.1</td>
<td>17.4</td>
</tr>
<tr>
<td>Other races</td>
<td>35.2</td>
<td>29.3</td>
<td>41.1</td>
<td>25.9</td>
</tr>
<tr>
<td>≥80 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>32.9</td>
<td>32.3</td>
<td>33.5</td>
<td>40.8</td>
</tr>
<tr>
<td>MA</td>
<td>62.5</td>
<td>61.6</td>
<td>63.3</td>
<td>81.5</td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>27.2</td>
<td>26.8</td>
<td>27.6</td>
<td>10.6</td>
</tr>
<tr>
<td>NH white</td>
<td>33.8</td>
<td>33.1</td>
<td>34.4</td>
<td>44.9</td>
</tr>
<tr>
<td>NH black</td>
<td>11.6</td>
<td>8.2</td>
<td>15.0</td>
<td>7.4</td>
</tr>
<tr>
<td>Other races</td>
<td>48.2</td>
<td>33.0</td>
<td>63.4</td>
<td>49.1</td>
</tr>
</tbody>
</table>

The difference was tested by Wald $\chi^2$. 95% CIs were combined according to DXA technical documentation, and $p$ value was summarized from five imputation DXA datasets. NS, non-significant.
controlling for covariates including participants’ demographics, dietary conditions, physical activity level, and obesity. Furthermore, our findings also suggest that maintaining BMI in a healthy range and doing muscle strengthening activity may exert beneficial effect against sarcopenia.

**Sarcopenia Prevalence and Risk Factors**

Sarcopenia has become an important global health issue, and the global average has reported to be 10% among individuals ≥60 years, which is close to the figure of our age group of 50–59 years (10.8%) but much lower than that of age groups above 60 years (17.3–32.9%) in the current study [22]. This further demonstrated the severe condition of sarcopenia prevalent in USA. When narrowing to diabetic individuals, epidemiological research identified a wide range of sarcopenia prevalence figure varying from 7% to 29% among different populations [23], which was comparable to the figure 27.9% identified in the current analyses. Scholars proposed that the disagreement of prevalence figures among different countries and population may partially source from the varied sarcopenia diagnosis criteria among studies: the predicted sarcopenia prevalence by FNIH has been found to be higher than European Working Group on Sarcopenia in Older People (EWGSOP) and International Working Group on Sarcopenia (IWGS), but lower than using ALM/weight or ALM/height [24]. For the current research, the involved survey cycles adopted inconsistent measurement of muscle strength/physical function; thus, it was impossible to adopt consistent criteria for muscle strength/physical function. Nonetheless, despite the possibility that the discrepancy is likely to come from different diagnostic protocols, the prevalence values found in this current study still remain high among all those existing researches, which indicates a severe comorbidity condition of the two diseases among US population when comparing with the world average. According to the recent reviews, the majority of the included studies reported positive relationship between DM and sarcopenia, and the prevalence of sarcopenia is significantly higher in DM individuals than nondiabetic individuals [25, 26]. Importantly, our analyses showed a 1.37 odds higher risk of sarcopenia in US diabetic population, which was comparable to the pooled figure reported by previous review which included small-moderate sample-sized research (OR 1.55; 95% CI 1.25–1.91) [25].

Demographics such as age, gender, and educational level have been suggested as possible predictors of the comorbidity conditions by previous research. The significant correlation between sarcopenia and age has been reported repeatedly in DM patients [23]. In consistent with our results, older adults face higher risk of suffering

---

**Fig. 1.** Sarcopenia prevalence of 50–59 years changes over time in diabetic and nondiabetic elders. Prevalence weighted for age, sex, race, and income.
### Table 5. Logistic regression between sarcopenia (yes/no) and diabetes and other risk factors

<table>
<thead>
<tr>
<th></th>
<th>Univariate model</th>
<th>Multivariate model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>UL</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.08</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1.31</td>
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</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50–59</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>60–69</td>
<td>1.72</td>
<td>1.36</td>
</tr>
<tr>
<td>70–79</td>
<td>3.00</td>
<td>2.35</td>
</tr>
<tr>
<td>80+</td>
<td>4.03</td>
<td>3.12</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
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<td></td>
</tr>
<tr>
<td>MA</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>0.64</td>
<td>0.44</td>
</tr>
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<td>NH white</td>
<td>0.36</td>
<td>0.29</td>
</tr>
<tr>
<td>NH black</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>Other races</td>
<td>0.53</td>
<td>0.37</td>
</tr>
<tr>
<td><strong>Educational level</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 9th grade</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>9–11th grade</td>
<td>0.55</td>
<td>0.41</td>
</tr>
<tr>
<td>High school grade</td>
<td>0.5</td>
<td>0.39</td>
</tr>
<tr>
<td>Some college</td>
<td>0.42</td>
<td>0.32</td>
</tr>
<tr>
<td>College graduate or above</td>
<td>0.27</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>≤18.5</td>
<td>1.75</td>
<td>0.58</td>
</tr>
<tr>
<td>25–29.9</td>
<td>3.45</td>
<td>1.21</td>
</tr>
<tr>
<td>≥30 (obesity)</td>
<td>7.39</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Muscle strengthening activity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0.5</td>
<td>0.39</td>
</tr>
<tr>
<td><strong>Physical activity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit during the day and do not walk about very much</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>Stand or walk about a lot during the day, but do not have to carry or lift things very often</td>
<td>0.72</td>
<td>0.62</td>
</tr>
<tr>
<td>Lift light load or have to climb stairs or hills often</td>
<td>0.58</td>
<td>0.44</td>
</tr>
<tr>
<td>Do heavy work or carry heavy loads</td>
<td>0.43</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Total protein intake (%E)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10–35</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>1.05</td>
<td>0.78</td>
</tr>
<tr>
<td>≥35</td>
<td>0.51</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>Total carbohydrate intake (%E)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45–65</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>&lt;45</td>
<td>0.89</td>
<td>0.69</td>
</tr>
<tr>
<td>≥65</td>
<td>1.00</td>
<td>0.73</td>
</tr>
<tr>
<td><strong>Total fat intake (%E)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–35</td>
<td>Ref</td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>1.03</td>
<td>0.73</td>
</tr>
<tr>
<td>≥35</td>
<td>1.03</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Physical activity, total protein, carbohydrate, and fat intake were not selected by stepwise selection model. OR, odds ratio; AOR, adjusted odds ratio; CI, confidence interval; LL, lower limit; UL, upper limit.
from the comorbidity of DM and sarcopenia. While controversial findings have been reported on the prevalence of sarcopenia between genders, a recent meta-analysis reported no gender difference on sarcopenia prevalence and another review study reported no significant difference in gender distribution of T2DM combined with sarcopenia [22, 23]. However, higher prevalence of sarcopenia has been reported in men with DM than their female counterparts, as gender has been found to be associated with body composition previously [23, 27]. Our findings suggested that male faces 1.96 odds higher risk of sarcopenia than female. Furthermore, educational level is a proxy for socioeconomic status. Our findings suggested that higher educational level was significantly associated with lower risk of sarcopenia, which is consistent to previous findings [28]. Obesity has also been raised as important influencing factors between the association of sarcopenia and DM [27]. Our findings suggested overweight and obese population faced higher risk of sarcopenia, as aging is associated with progressive muscle loss and the changes in body composition [29].

**Preventing Sarcopenia and DM**

Sarcopenia has been thought as one of the complications of DM [26, 30]. However, the belief grows that sarcopenia and DM are comorbidities, and that sarcopenia may also exacerbate DM, as low lean mass may exert adverse effect on glucose disposal and insulin sensitivity [31–33]. Hyperglycemia has been considered as one of the main risk factors between sarcopenia and DM. Hyperglycemia would promote the accumulation of middle and late glycosylation end products, which could induce skeletal muscle atrophy and dysfunction [34]. Impaired mitochondrial function in skeletal muscle has been found in diabetic patients, which leads to the dysfunction of skeletal muscle metabolism. Insulin resistance, a well-known major pathological condition of prediabetes and DM, has been reported as the underlying cause of both hyperglycemia and mitochondrial dysfunction, and the association with impaired lipid and protein metabolism has also been reported [32, 35]. Anti-DM medication, including insulin and insulin sensitizers, has been found to attenuate skeletal muscle loss in diabetic patients [36, 37]. However, our subgroup analysis indicates that using anti-DM medication (insulin or pills to lower blood sugar) did not decrease the sarcopenia prevalence among the diabetic participants (online suppl. Table 10). The duration of using anti-DM medication may also be an important factor to show observable effect on muscle mass, but the related data were not available from NHANES [37]. Though several biological receptors have been discovered to attenuate muscle mass in diabetic patients, more clinical studies on human populations are needed [37].

Muscle strengthening activity, restricted calorie intake, sufficient nutrient intake, and circadian rhythms could be the controllable factors for routine management [38, 39]. Our findings enforce the importance of interventions, as healthy BMI and muscle strengthening activity may improve skeletal muscle mass and quality for diabetic individuals. Regular moderate physical exercise (mostly 150 min per week) has been suggested for T2DM [40]. The combination of aerobic and resistance exercise has been found to be more effective to glycemic control than single aerobic or resistance training alone [41]. Resistance training has also been found fundamental to sarcopenia prevention, but older population tend to be hesitant for resistance training and would prefer easy activities [42].

Dietary intake has been considered as controllable risk factors for chronic diseases [15]. Protein and essential amino acid supplementation have been suggested to maintain muscle mass and function due to the stimulatory effect on muscle protein synthesis [14]. Similar to our results, Shikany et al. [43] reported no significant effect from dietary protein intake. In our study, only 0.2% of the included participants took protein exceeding acceptable macronutrient distribution range, resulting in insignificant statistical results. As age-related skeletal muscle loss may lead to frailty, sarcopenia, and the onset of DM, controlling dietary macronutrient intake to maintain protein synthesis may slow the progression of sarcopenia. On the other hand, several studies reported the beneficial effect against sarcopenia [43–45]. Increasing the percentage of fat intake in diet may also attenuate muscle loss via lowering blood sugar or insulin [15].

Up to date, no specific management guideline or dietary macronutrient recommendations have been developed for the prevention from sarcopenia. Our findings of high prevalence of sarcopenia among individuals with DM suggest that muscle strengthening activity is essential for preventing both sarcopenia and DM. Further studies on the recommendations of dietary intake and efficient resistance training are strongly required.

**Strengths and Limitations**

NHANES is a nationally representative survey and has been strictly designed that allows comprehensive evaluation on the severe research question of sarcopenia and DM. We have adopted thorough definition for DM and accurate estimation of ALM measured by DXA, which is a validated method for measuring body composition compared to bioelectrical impedance analysis. Moreover, except for DM status, we also included the potential predictors of the
prevalence of sarcopenia such as age, gender, ethnicity, educational level, dietary conditions, obesity, physical activity. According to the best of our knowledge, this is the first study which examined the relationship between sarcopenia and diabetic elders in a comprehensive national level. Nonetheless, there remain a few limitations. According to recent summary of sarcopenia diagnosis, muscular function is gradually considered as part of the diagnosis criteria as well as ALM. Limited muscular functional data were accessible; thus, we were only able to define sarcopenia by adopting the formerly used criteria. Another limitation of NHANES, as a cross-sectional study, is the susceptibility to biases sampling, though NHANES endorsed a complex study design and statistical adjustment to reduce the bias. Future longitudinal studies are warranted to further confirm our findings [46].

Conclusion

Our study presented a nationally representative estimation for the prevalence of sarcopenia among population above 50 years and the participants with and without DM. Our study found the overall prevalence of sarcopenia among US elder population was above the world average, and diabetic elders faced significant higher risk than their nondiabetic counterparts. Gender, age, ethnicity, educational level, and obesity were important risk factors of sarcopenia development. Daily management is strongly suggested to incorporate muscle strengthening activity and body weight management in order to prevent both sarcopenia and DM. Future research should investigate the efficacy of routine management and provide advisory in disease prevention and control for patients with sarcopenia and DM.

Acknowledgments

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References


Statement of Ethics

The ethical approval of NHANES was granted by the US National Center for Health Statistics Research Ethics Review Board (Protocol No. 98-12, Protocol No. 2011-17, Continuation of Protocol No. 2011-17, Protocol No. 2018-01) (available at: https://www.cdc.gov/nchs/nhanes/irba98.htm). The NHANES is a publicly available dataset. The analysis in this study is a secondary analysis of NHANES data; thus, ethical approval is exempted under the US Health and Human Services (HHS) regulations at 45 CFR 46.104 (available at: https://www.hhs.gov/ohrp/regulations-and-policy/regulations/45-cfr-46/common-rule-subpart-a-46104/index.html). Written informed consent was acquired before household interview and health examinations; the participants were assured that the data collected will be used only for stated purposes and will not be disclosed or released to others without the consent (available at: https://www.cdc.gov/nchs/nhanes/genetics/genetic_participants.htm).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

S. Dai and D. Shu contributed equally to drafting the manuscript; S. Dai, W. Guo, and F. Chen contributed to the study design and critical revision; W. Guo and F. Chen contributed to data analysis; J. Wang, F. Meng, Y. Chen, X. Liu, and X. Xiao provided valuable advice to this study and contributed to revising the manuscript; all authors reviewed the manuscript and approved the final version for publication.

Data Availability Statement

All data were retrieved from National Health and Nutrition Examination Survey from the US CDC; all data are publicly available. Further inquiries can be directed to the corresponding authors.

References


