

ORIGINAL RESEARCH

# ECONOMIC IMPACT OF HOSPITALIZATIONS IN US ADULTS WITH SARCOPENIA

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**Abstract:** *Background:* Sarcopenia is characterized by progressive loss of muscle mass with corresponding decline in strength and/or physical function. The economic burden of sarcopenia-associated disability is considerable in the US. *Objective:* To estimate the cost of hospitalizations in US adults with sarcopenia categorized by age, sex, and race/ethnicity. *Design, setting and participants:* A retrospective, prevalence based, economic burden study, consisting of 4011 adults aged  $\geq 40$  years with and without sarcopenia. *Methods:* Data on prevalence of low lean mass, functional limitations, and hospitalizations were obtained from the National Health and Nutrition Examination Survey (1999-2004); cost of hospitalizations was obtained from the Healthcare Cost and Utilization Project - National Inpatient Sample (2014), and population estimates were obtained from the US Census (2014). Probability and cost of hospitalizations were estimated by multiple logistic regression and negative binomial regression models, respectively. *Results:* The total estimated cost of hospitalizations in individuals with sarcopenia was USD \$40.4 billion with an average per person cost of USD \$260. Within this category, average per person cost was highest for Hispanic women (USD \$548) and lowest for Non-Hispanic Black women (USD \$25); average per person cost was higher for older adults ( $\geq 65$  years) (USD \$375) than younger adults (40-64 years) (USD \$204) with sarcopenia. The total cost of hospitalizations in individuals with sarcopenia ( $\geq 65$  years) was USD \$19.12 billion. Individuals with sarcopenia had greater odds of hospitalization (OR, 1.95;  $p < .001$ ) compared to those without and had an annual marginal increase in cost of USD \$2315.7 per person compared to individuals without sarcopenia. *Conclusion:* Sarcopenia places considerable economic burden on the US healthcare system. The ethnic disparity and economic burden associated with sarcopenia warrant further investigation.

**Keywords:** Cost, hospitalization, economic burden, race, sarcopenia.

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## Introduction

Sarcopenia, characterized by a progressive loss of muscle mass and decline in strength and/or physical function over time (1-3) is associated with a high risk of mobility-disability, decreased quality of life, increased burden of treatment and caregiving, and increased mortality (4, 5). The condition has also been considered a precursor syndrome or physical manifestation of frailty (6). Sarcopenia is becoming a significant public health issue at both patient and societal levels, especially in countries with a growing proportion of older adults (4) and for the first time, sarcopenia in older adults has been identified as a topic/scientific question to be examined by the U.S. 2020 Dietary Guidelines Advisory Committee (7). Yet, there have been limited investigations that have considered the economic burden of sarcopenia. To identify sarcopenia in the clinic, a variety of measures have been proposed for estimating muscle mass, physical strength and function (1) and the proposed cut points for many of these measures are still under investigation to determine what is most clinically relevant. In addition, a self-reported questionnaire on functional ability (SARC-F) has been validated as a practical tool to identify sarcopenia in the community (8). This tool

was found to have comparative predictive power in predicting 4-year physical limitations as the other quantitative means of identifying sarcopenia (9).

Although the term sarcopenia is used to describe a condition associated with low muscle mass and associated strength/physical function changes in older adults, a similar condition has been observed in relatively younger adults with chronic disease (10, 11). In these younger individuals, their chronic disease predisposes them to premature loss of muscle mass with associated loss of function that leads to mobility-disability, decreased quality of life and even mortality, similar to that observed in older individuals with sarcopenia (10, 12); thus there is likely to be an economic impact from these sarcopenia-like changes in body composition as well. The recently revised European consensus on the definition and diagnosis of sarcopenia recommends categories of sarcopenia, with primary sarcopenia categorized as aging-related and secondary sarcopenia when occurring secondary to systemic disease, especially one that causes inflammation (2). Therefore, younger individuals were also included in the present study. Race or ethnicity and sex may contribute to change in skeletal muscle mass over time, (13) and Hispanics (14) and women, (5) have been reported to have a higher prevalence of sarcopenia

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compared to other racial/ethnic groups and men, respectively.

Extended immobilization such as periods of hospitalization can cause severe muscle and function loss especially in older adults (15). In hospitalized patients, sarcopenia has been associated with increased number of days spent in bed, (16) worsened prognosis, and increased mortality (17). The prevalence of sarcopenia among hospitalized patients is estimated to range from 14-40% depending on age, sex and nutrition status (16, 18). According to a 2002 estimate (the most recent available) in the United States, the economic burden of sarcopenia-associated disability was USD \$18.5 billion, including hospitalization, nursing home admissions, and home healthcare costs (19). In that study, sarcopenia was defined by the occurrence of low muscle mass only, since the study was conducted prior to the more recent definitions of sarcopenia that recommend inclusion of loss of strength/function (1). Since then, there have been no new estimates on the economic burden of sarcopenia using current sarcopenia definitions and hospital spending data. To our knowledge there have been no studies estimating the economic burden of sarcopenia in younger populations (secondary sarcopenia) in the US. In this retrospective analysis, we present updated data on the economic impact of hospitalization among US adults with sarcopenia stratified by age, sex, and race/ethnicity.

### Methods

Prevalence data of sarcopenia and self-reported number of hospitalizations were obtained from the National Health and Nutrition Examination Survey (NHANES). The NHANES is a series of cross-sectional surveys that includes a nationally representative sample of non-institutionalized Americans, and collects demographic, socioeconomic, and dietary data. Anthropometric parameters such as height, weight, and body composition are also recorded. To increase the reliability of data for certain population subgroups, NHANES uses a complex, multistage probability sampling design. To estimate unbiased population statistics, individual NHANES observations are weighted to account for differential probability of survey inclusion. Where appropriate in our analysis, we report results both for the 'sample' that we analyzed (unweighted), and for the 'population as a whole' (weighted). All data, study design and procedures, and examination and laboratory components are publicly available online at <http://www.cdc.gov/nchs/nhanes.htm> (20).

For the present study, adults (aged  $\geq 40$  years) who had body composition data were included in the analysis. We only considered data from NHANES 1999 to 2004 because that was the most recent time period that allowed for identification of sarcopenia using appendicular lean mass (ALM) measurements obtained by dual-energy X-ray absorptiometry (DEXA). NHANES stopped collecting DEXA data after the 1999-2004 period. Pregnant females and individuals who were taller than 192.5 cm (6'5") or weighed more than 136.4 kg (300 lbs) did

not receive the DEXA examination and were excluded. Total fat mass, total lean mass, bone measurements, and total body fat percent were assessed in NHANES participants using DEXA. The appendicular lean mass index (ALMI) was calculated as the sum of the muscle mass of both right and left arms and legs divided by the individual's body mass index (BMI).

Individuals with sarcopenia were defined as adults (age  $\geq 40$  years) with: 1) low ALMI using the recommended cutpoints proposed by the Foundation for the National Institutes of Health sarcopenia consortium (ALMI,  $< 0.789$  kg/m<sup>2</sup> for men and  $< 0.512$  kg/m<sup>2</sup> for women) (3); and 2) self-reported functional limitations collected in NHANES through a physical function questionnaire. Functional limitation was defined as self-reported difficulty in performing one or more of the following activities: walking 0.25 mile; walking up 10 stair steps without resting, stooping, crouching or kneeling; lifting or carrying 10 pounds, walking between rooms on the same floor, standing up from an armless chair, or getting in and out of bed.

The economic burden of hospitalizations associated with sarcopenia/sarcopenia-like conditions was analyzed by race/ethnicity, age, and sex of the NHANES participants. Race or ethnicity was categorized into non-Hispanic Whites (NH Whites), non-Hispanic Blacks (NH Blacks), Hispanics, and Others as defined by the NHANES. To reflect the current demographics of the United States as closely as possible, the population size of these groups was modeled using 2017 projections of the 2014 US Census (Supplemental Figure 1).

### Analysis

#### Cost estimation

The NHANES dataset does not include any healthcare cost information. Thus, as is standard practice when primary data is not available for an economic analysis, the hospitalization costs for NHANES respondents were imputed using the Healthcare Cost and Utilization Project- National Inpatient Sample (HCUP-NIS, 2014) dataset. This is the largest all-payer inpatient database in the US, providing nationally representative estimates of diagnoses, lengths of hospital stays, total charges, and demographics (21). Charge data from the HCUP-NIS dataset was converted into cost data, using cost-to-charge ratios provided by Agency for Healthcare Research and Quality (AHRQ) (22). Then, the average cost of a hospital admission was calculated for each subgroup in the analysis. Total annual hospital cost was imputed as the subgroup specific average episode cost multiplied by the number of self-reported stays of the NHANES respondent. This approach assumes (conservatively) that any increase in total cost associated with sarcopenia is a result of more hospitalizations, not a higher cost per hospitalization.

The marginal impact of sarcopenia on the number of hospitalizations and total annual hospital cost was estimated using two-part multivariate regression models. The first step of the two-part regression was identical for both the estimate

**Table 1**

Population summary statistics (N=4011, population mean corrected for complex survey design using survey weights)

| Variable  | Sample Mean | Sample N | Population Mean | Population SE |
|---|-------------|----------|-----------------|---------------|
| Age (Years)   | 67.2        | 4011     | 64.2            | 0.29          |
| Number of overnight hospital stays                    | 0.2         | 4011     | 0.2             | 0.013         |
| Appendicular Lean Mass Index (ALM/kg/m <sup>2</sup> ) | 0.7         | 4011     | 0.7             | 0.003         |
| BMI (kg/m <sup>2</sup> )                              | 27.6        | 4011     | 27.7            | 0.94          |
| Male, n (%)   | 49.7        | 1993     | 44.8            | 0.008         |
| Age distribution, n (%)                               |             |          |                 |               |
| 40-54   | 13.7        | 550      | 22.9            | 0.012         |
| 55-64   | 24.8        | 995      | 24.7            | 0.010         |
| 65-74   | 34.5        | 1383     | 31.9            | 0.010         |
| 75-84   | 21.7        | 870      | 17.2            | 0.008         |
| >=85  | 5.3         | 230      | 3.2             | 0.003         |
| Race/Ethnicity distribution, n (%)                    |             |          |                 |               |
| Non-Hispanic White                                    | 55.8        | 2236     | 79.8            | 0.018         |
| Non-Hispanic Black                                    | 16.5        | 660      | 8.7             | 0.010         |
| Hispanic  | 25.4        | 1017     | 8.3             | 0.015         |
| Other/Not Identified                                  | 2.4         | 98       | 3.2             | 0.005         |
| Sarcopenia, n (%) (Age 40-64)                         | 10.7        | 166      | 8.8             | 0.011         |
| Sarcopenia, n (%) (Age ≥65)                           | 18.9        | 441      | 15.4            | 0.001         |

BMI Body mass index; SE Standard error

of hospitalizations and the estimate of total hospital cost. The probability of at least one hospitalization (as self-reported in NHANES) was estimated using logistic regression. For evaluating the impact of sarcopenia on hospital stays, a negative binomial regression was used as the second part of the two-part model with the self-reported count of hospital stays, given that the individual had at least one stay. Similarly, for evaluating the impact of sarcopenia on annual hospital cost, we regressed imputed annual hospital cost on sarcopenia using a negative binomial regression. For all regressions, independent variables were sarcopenia, age (categorized as 40-54, 55-64, 65-74, 75-84, 85+), race/ethnicity, and sex. Regressions were appropriately weighted for the complex survey design of NHANES and results reported as marginal impact of explanatory variables. Marginal cost of sarcopenia for each subgroup was estimated.

The economic burden of sarcopenia was calculated in USD (value in year 2014). Total economic burden for each subgroup (age, race/ethnicity, sex) was calculated by multiplying the number of individuals in the population (based on population data from the US Census), subgroup-specific sarcopenia prevalence (from NHANES), and marginal cost of hospitalization associated with having sarcopenia (estimated as described above).

#### *Sensitivity analysis*

To evaluate the robustness of the results, sensitivity analysis was performed using Monte Carlo simulations incorporating the variability in data obtained from HCUP-NIS and NHANES. Episode cost was modeled (based on HCUP-NIS data) using a negative binomial distribution with subgroup specific parameterizations. A subgroup-specific ‘average cost’ was drawn from this distribution for each subgroup, for each simulation. The NHANES dataset was resampled with replacement accounting for the probability weighting using `svybsamp2`, a STATA module for resampling (23). Simulations were conducted for 1000 iterations and inter quartile ranges (IQR) are reported.

#### **Results**

A total of 4011 individuals from the NHANES dataset were included in the sample. The sample and the population statistics slightly varied due to the complex survey design used in NHANES. The mean age was 67.2 years for the sample and 64.2 years for the population. A total of 49.7% individuals were male in the sample, while the population included 44.8% male. The number of overnight hospital stays per year, ALMI, and BMI were similar in both the sample and the population. Comparison of the distribution of age and race/ethnicity showed that the NHANES survey oversampled older adults and

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**Table 2**

Two-part regression model to estimate the marginal increase in hospital stay and cost of hospital stay by age, sex, and race/ethnicity

| Variable                       | Odds Ratio from Logistic Regression (95 % CI) | Negative Binomial Regression Coefficient of Hospital Stay (95 % CI) | Marginal Increase in Hospital Stay (95 % CI) | Negative Binomial Regression Coefficient of cost (95 % CI) | Marginal Increase in Cost (95 % CI) |
|--------------------------------|---|---|--|--|-------------------------------------|
| Men (vs. Women)                | 0.95 (0.77, 1.18)                             | -0.03 (-0.17, 0.10)   | -0.02 (-0.06, 0.03)                          | -0.03 (-0.17, 0.11)  | -186.88 (-695.23, 321.46)           |
| Age (vs. 40-54)                |   |   |  |  |                                     |
| 55-64                          | 0.72* (0.54, 0.98)                            | -0.14 (-0.36, 0.07)   | -0.09 † (-0.16, -0.02)                       | 0.11 (-0.10, 0.32)   | -403.26 (-1139.31, 332.79)          |
| 65-74                          | 0.79 (0.60, 1.05)                             | -0.13 (-0.36, 0.11)   | -0.07 (-0.15, 0.00)                          | 0.21 (-0.02, 0.45)   | 31.41 (-842.56, 905.38)             |
| 75-84                          | 0.92 (0.67, 1.26)                             | -0.22* (-0.39, -0.40)   | -0.07 † (-0.13, -0.00)                       | 0.05 (-0.13, 0.23)   | -38.70 (-740.74, 663.35)            |
| 85+                            | 0.74 (0.48, 1.15)                             | -0.12 (-0.45, 0.20)   | -0.08* (-0.16, -0.01)                        | -0.01 (-0.34, 0.32)  | -612.68 (-1389.97, 164.60)          |
| Race/Ethnicity (vs. White)     |   |   |  |  |                                     |
| Black                          | 1.49 † (1.12, 1.98)                           | 0.17 (-0.04, 0.38)  | 0.12 † (0.04, 0.21)                          | 0.15 (-0.06, 0.37)   | 1455.43 † (409.56, 2501.30)         |
| Hispanic                       | 1.57* (1.09, 2.25)                            | -0.07 (-0.31, 0.17)   | 0.07 (-0.00, 0.14)                           | -0.01 (-0.25, 0.23)  | 1027.54* (122.17, 1932.91)          |
| Other                          | 0.89 (0.47, 1.71)                             | 0.33* (-0.04, 0.70)   | 0.05 (-0.10, 0.20)                           | 0.48* (0.10, 0.86)   | 1093.11 (-1046.51, 3232.73)         |
| Sarcopenia (vs. no sarcopenia) |   |   |  |  |                                     |
|                                | 1.95 ‡ (1.47, 2.59)                           | 0.14 (-0.05, 0.34)  | 0.18 ‡ (0.09, 0.28)                          | 0.15 (-0.04, 0.34)   | 2315.69 ‡ (1092.57, 3538.80)        |
| Constant                       | 0.16 ‡ (0.12, 0.21)                           | 0.48 ‡ (0.27, 0.69)   | N/A  | 9.68 ‡ (9.47, 9.90)  | N/A                                 |

CI: Confidence interval. The first column is the odds ratio of having any overnight hospital stays in the previous year using logistic regression. The second column is the negative binomial coefficient estimate for the count of stays given at least one stay. The third column is the marginal increase in hospital stay calculated from the two-part model. The fourth column is the negative binomial coefficient estimate for the cost of hospital stay. The fifth column is the marginal increase in cost of hospital stay calculated from the two-part model. \*p<0.05; †p<0.01; ‡ p<.001.

minority groups vs. the population (Table 1).

Overall, 607 (15.1%) individuals with sarcopenia were identified in the sample, and 12.3% of the population had sarcopenia (Supplemental Table 1). Prevalence was not significantly different by sex (women: 12.1%; men: 12.5%). Across the race/ethnic groups, Hispanics had the highest prevalence of sarcopenia and NH blacks had the lowest prevalence. Prevalence of sarcopenia was higher among older adults (women: 15.2%; men: 15.7%) compared to younger adults (women: 8.5%; men: 9.1%). Within the older age group, sarcopenia was most prevalent among Hispanics (women: 27.1%; men: 26.5%) and least prevalent among NH Blacks (women: 1.6%; men: 8.6%) (Supplemental Table 1).

Individuals with sarcopenia had about twice the odds of hospitalization (OR, 1.95; p<.001) and an average 0.18 (p<.001) more hospital stays compared with individuals without sarcopenia. This leads to an average estimated marginal cost increase of USD \$2315.7 (p<.001) in annual hospital spending for individuals with sarcopenia compared to those with normal muscle mass and function (Table 2).

The total annual cost of hospitalization for individuals with sarcopenia was USD \$40.4 billion with an average per person cost of USD \$260. The total cost was higher in younger adults (USD \$21.3 billion) compared to older adults (USD \$19.1 billion). However, average cost per person was greater for older adults (USD \$375) compared to younger adults (USD \$204). Total cost was found to be higher in women (USD \$21.7 billion) compared to men (USD \$18.7 billion). Average cost per

person was highest for Hispanic women (USD \$548) and lowest for NH Black women (USD \$25) (Table 3).

**Discussion**

Both sarcopenia and frailty are characterized by a unique core condition, physical function impairment, which may result in disability as well as may be a direct consequence of disability (24). The economic analysis presented in this study contributes to the scientific body of evidence on sarcopenia using more recent US economic data and taking into consideration the revised definition of sarcopenia to include the clinical impact of loss of lean mass on physical function. The findings of this study show that sarcopenia is a common and costly condition in older adults. In addition, the data show that even in younger adults, the prevalence of low lean mass with associated loss of function is relatively high, and across age groups this condition disproportionately impacts the Hispanic population.

In one of the first economic burden studies of sarcopenia in US adults published in 2004, prevalence estimates were based on NHANES data from 1994. In that study, sarcopenia was defined using the cut points for low skeletal muscle index (SMI) based on distribution characteristics of a population; and the study did not account for the clinical manifestations of low lean mass-strength and/or function loss. The cost of disabilities was assessed in older men and women (≥60 years of age) with moderate to severe muscle loss (19). In the present study, we provided an updated cost estimate of hospitalizations

**Table 3**  
Cost of hospitalizations in people with sarcopenia by age, sex and race/ethnicity

| Age ≥40 (Combined Age 40-64 and Age ≥65), (n=4011) |                  |               |                  |               |                  |               |                  |                |
|--|------------------|---------------|------------------|---------------|------------------|---------------|------------------|----------------|
| Total group cost                                   | 40.4 (31.6-52.6) |               |                  |               |                  |               |                  |                |
| Average cost per capita                            | 260 (203-339)    |               |                  |               |                  |               |                  |                |
|  | Men (n=1993)     |               |                  |               | Women (n=2018)   |               |                  |                |
| Total group cost                                   | 18.7 (14.2-24.6) |               |                  |               | 21.7 (16.7-28.0) |               |                  |                |
| Average cost per capita                            | 253 (192-334)    |               |                  |               | 266 (204-343)    |               |                  |                |
|  | White (n=1131)   | Black (n=327) | Hispanic (n=486) | Other (n=49)  | White (n=1105)   | Black (n=333) | Hispanic (n=531) | Other (n=49)   |
| Total group cost                                   | 12.4 (9.5-16.8)  | 0.6 (0.3-0.7) | 3.7 (2.7-4.8)    | 2.0 (0.8-2.8) | 13.7 (10.2-18.2) | 0.2 (0.1-0.3) | 5.6 (4.1-7.2)    | 2.1 (1.0-2.8)  |
| Average cost per capita                            | 242 (185-327)    | 72 (45-89)    | 383 (277-493)    | 397 (169-561) | 246 (183-324)    | 25 (12-32)    | 548 (398-699)    | 356 (172-480)  |
| Age 40-64 (n=1545)                                 |                  |               |                  |               |                  |               |                  |                |
| Total group cost                                   | 21.3 (17.2-29.7) |               |                  |               |                  |               |                  |                |
| Average cost per capita                            | 204 (165-285)    |               |                  |               |                  |               |                  |                |
|  | Men (n=746)      |               |                  |               | Women (n=799)    |               |                  |                |
| Total group cost                                   | 10.4 (8.2-14.5)  |               |                  |               | 10.9 (8.6-15.4)  |               |                  |                |
| Average cost per capita                            | 203 (161-284)    |               |                  |               | 205 (162-289)    |               |                  |                |
|  | White (n=368)    | Black (n=155) | Hispanic (n=199) | Other (n=24)  | White (n=371)    | Black (n=164) | Hispanic (n=238) | Other (n=26)   |
| Total group cost                                   | 6.6 (5.1-9.6)    | 0.04 (0-0.06) | 2.4 (1.7-3.2)    | 1.3 (0.4-2.0) | 6.3 (4.9-9.2)    | 0.08 (0-0.14) | 3.8 (2.7-5.0)    | 0.8 (0.3-1.3)  |
| Average cost per capita                            | 197 (152-285)    | 7 (0-10)      | 299 (217-409)    | 355 (117-537) | 184 (141-268)    | 13 (0-20)     | 467 (343-627)    | 194 (64-295)   |
| Age ≥65, (n=2466)                                  |                  |               |                  |               |                  |               |                  |                |
| Total group cost                                   | 19.1 (13.6-22.7) |               |                  |               |                  |               |                  |                |
| Average cost per capita                            | 375 (267-445)    |               |                  |               |                  |               |                  |                |
|  | Men (n=1247)     |               |                  |               | Women (n=1219)   |               |                  |                |
| Total group cost                                   | 8.4 (5.9-10.2)   |               |                  |               | 10.8 (7.5-12.7)  |               |                  |                |
| Average cost per capita                            | 368 (259-449)    |               |                  |               | 380 (264-449)    |               |                  |                |
|  | White (n=763)    | Black (n=172) | Hispanic (n=287) | Other (n=25)  | White (n=734)    | Black (n=169) | Hispanic (n=293) | Other (n=23)   |
| Total group cost                                   | 5.8 (4.1-7.2)    | 0.5 (0.3-0.6) | 1.4 (0.9-1.6)    | 0.7 (0.2-0.9) | 7.4 (5.2-8.9)    | 0.2 (0.1-0.2) | 1.9 (1.3-2.2)    | 1.3 (0.5-1.6)  |
| Average cost per capita                            | 327 (229-404)    | 277 (167-344) | 752 (483-874)    | 523 (208-690) | 342 (242-413)    | 54 (22-68)    | 817 (525-938)    | 787 (336-1021) |

Costs were estimated for year 2014; Total group costs were expressed as Billion USD (IQR); Average costs were expressed as USD (IQR). n, number of individuals; IQR, Inter Quartile Range

in persons with sarcopenia across age and race/ethnic groups using the newer sarcopenia definitions that take into account the functional declines (1, 3).

Results of the present study reinforce that individuals with sarcopenia put a considerable burden on the US health economy with Hispanics and older adults being the groups with highest per capita burden. The present study supports the earlier findings of Janssen et al that sarcopenia is a significant and costly public health problem (19). We found that hospitalization costs for individuals with sarcopenia add up to USD \$40.4 billion annually, representing a sizable share of total National Health Expenditures (NHE) on hospital care (USD \$981.0 billion in 2014) (19). Also, in the present study, total cost was found to be higher in women compared to men unlike the findings of Janssen et al (19). One possible reason for this may be a greater percentage of women in our analysis, which

also reflects a greater proportion of women in the US older adult population (25). Although our study showed that the total cost of hospitalization was higher in younger adults compared to older adults, this is because younger adults constitute a larger proportion of the population. On a cost per person basis, average cost was greater for older adults compared to younger adults. Our study also showed that compared to people with normal muscle mass and function, people with sarcopenia have greater odds of hospitalization and on average more hospital stays, contributing to an increased economic burden.

Older age, non-white race, and female sex are significant predictors of poor healthcare coverage (26), although the Affordable Care Act has significantly increased opportunities for coverage among the uninsured (27). Sarcopenia could amplify healthcare costs for those with limited insurance, particularly older adults. Results of the present study suggest

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that older adults had a higher burden with an average cost per person of USD \$375 compared to USD \$204 for younger adults. Although older adults are eligible for healthcare coverage through Medicare, studies suggest that even Medicare beneficiaries may have gaps in coverage (28) and may have high out-of-pocket expenses for insurance supplemental to Medicare (29).

The present study also shows that Hispanic adults had a higher cost of hospitalization associated with sarcopenia compared to other racial groups and across age groups. In 2015, Hispanics had the lowest rates of insurance coverage (83.8% were insured) compared to Whites (93.3%), Asians (92.5%), and Blacks (88.9%) (29, 30). Residency status and restrictions on eligibility for coverage, individual lack of awareness about eligibility, and language barriers, all can limit healthcare access for Hispanics (31). Considering the high cost of sarcopenia and poor healthcare outcomes, this subpopulation requires special attention, and programs such as the Latino Integrative Nutrition Initiative are working to help raise awareness about sarcopenia in the Hispanic population.

Based on current clinical evidence, preventive measures such as increasing physical activity and improving nutrition quality (increased protein intake, use of specialized nutrients that enhance muscle metabolism) should be considered to help improve muscle function in older adults towards reducing the burden of sarcopenia (32, 33). As sarcopenia has been related to poor functionality, falls prevention programs such as the CDC's Stopping Elderly Accidents, Deaths and Injury (STEADI) program may provide benefit in this population as well (34). Recently the World Health Organization (WHO) issued specific guidelines on managing declines in intrinsic capacity in community dwelling older adults (35). These guidelines recommend the use of multimodal exercise and oral supplemental nutrition with dietary advice for older people affected by undernutrition and declining physical capacity.

The present study has some limitations. Because the NHANES dataset from 1999-2004 did not include quantitative measures of strength/function such as gait speed or grip strength, individuals with low physical function were identified based on self-reports, which may be biased. However, self-reported questionnaires on physical function are now being developed as a practical way to screen for sarcopenia in the community (8). In the present study, prevalence of sarcopenia was limited to NHANES surveys for years 1999-2004. Unfortunately, NHANES stopped collecting body composition (DEXA) data in subsequent years so it was not possible to use the more recent NHANES data for this analysis. Currently there are very limited open-access large US population datasets that have body composition data in conjunction with strength and physical function data. It is possible that prevalence rates have changed since the 1999-2004 data were collected and this is indeed a limitation of this study. Also, since no direct measure of hospitalization cost for sarcopenia/sarcopenia-like conditions was available in NHANES, costs for hospitalization episodes

were imputed using HCUP-NIS. Thus, our estimates of increased hospitalization cost did not control for the diagnoses associated with increased hospitalizations.

This study highlights the considerable economic burden placed on the US health care system by sarcopenia. The study also underscores the cost disparity between different racial/ethnic and age groups. There is a need to increase awareness of the importance of maintaining body composition and preserving lean mass and function in adulthood as well as to increase awareness about the negative public health consequences of developing sarcopenia. There is also a need to promote change in clinical practice towards systematic screening for older adults at risk of developing sarcopenia and early intervention to support healthy aging. The racial/ethnic disparities in the burden of sarcopenia warrant further investigation and consideration in population-targeted health screening and intervention programs, particularly those focused on older adults.

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