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Association between daily sitting time and sarcopenia in the US population: a cross-sectional study

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Abstract

Background Sarcopenia is an age-related syndrome marked by a gradual decline in skeletal muscle mass and function. While various factors influencing sarcopenia have been studied, the link between daily sedentary time and sarcopenia remains underexplored.

Method This study analyzed the association between daily sitting time and sarcopenia using data from the National Health and Nutrition Examination Survey (NHANES 2011–2018). Daily sitting time was assessed through questionnaires, while sarcopenia was measured using body mass index (BMI) adjusted appendicular skeletal muscle mass (ASM). The relationship was analyzed using weighted logistic regression models and smoothing curves. Stratified analyses and interaction testing were employed to investigate population-specific characteristics of this association. Furthermore, chi-square test and grouped logistic regression were used to further analyze the impact of vigorous activity on the relationship between the two variables.

Result This study included 9998 participants with complete information. The fully adjusted model showed a significant positive correlation between daily sitting time and the prevalence of sarcopenia (OR = 1.07, 95% CI: 1.03–1.10, $P = 0.0026$). The group with daily sitting time ≥ 9 h had a 90% higher risk of sarcopenia compared to the < 4 h group (OR = 1.90, 95% CI: 1.22–2.84, $P = 0.0040$). Smooth curve fitting analysis showed a linear correlation between this relationship. Stratified analysis shows that non-Hispanic white men with a lower BMI (BMI < 25) have a higher risk of sarcopenia. Compared to those who actively participate in vigorous activities, individuals who lack recreational activities have a higher prevalence and risk of sarcopenia.

Conclusion Our research has found that increased sedentary time significantly increases the risk of sarcopenia, especially among non-Hispanic white men with lower BMI. Additionally, individuals who lack vigorous physical activity also have a higher prevalence and risk of sarcopenia. Therefore, reducing sedentary behavior and increasing moderate exercise may be effective prevention strategies.

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Keywords Daily sitting time, Sarcopenia, NHANES, Positive association, Recreational activities

Text box 1. Contributions to the literature

- Large-scale population studies indicate that over 60.05% of participants sit for more than 6 h each day, and prolonged sitting time is significantly positively correlated with sarcopenia.
- Non-Hispanic white men with low BMI and a lack of recreational activities face a higher risk of developing sarcopenia.
- There is an urgent need to promote public health policies to reduce sedentary behavior and increase physical activity to address sarcopenia.

Introduction

In recent years, sedentary behavior has become a major public health issue, distinct from physical inactivity. Sedentary lifestyles are widespread in modern society, referring to low-energy activities (≤1.5 metabolic equivalents) performed while sitting, reclining, or lying down during waking hours [1]. This behavior is associated with various health problems, including low back pain, cardiovascular diseases, diabetes, cancer, and mental health issues [2–4]. Large-scale epidemiological studies have shown that sedentary behavior not only increases the risk of cardiovascular events but is also closely linked to all-cause mortality [5]. The latest global guidelines on physical activity and sedentary behavior recommend limiting sedentary time and improving physical health by increasing physical activity [6].

Sarcopenia is a systemic, progressive skeletal muscle disease characterized by a gradual decline in muscle mass and function [7]. Studies show that it affects 10–16% of the elderly globally [8], and is closely linked to various adverse health outcomes such as falls, fractures, functional impairment, disability, and all-cause mortality [8–10]. Moreover, sarcopenia is associated with increased cardiovascular risk, including hyperglycemia, hypertension, insulin resistance, and cardiovascular disease [11–13]. Its presence not only impairs quality of life, but also significantly increases the risk of hospitalization and healthcare costs [14, 15]. As global aging intensifies, the number of affected individuals is expected to exceed 500 million by 2050 [16]. Although the exact causes of sarcopenia are not yet fully understood, it is generally believed to be related to factors such as age, malnutrition, lack of exercise, metabolic disorders, and oxidative stress [17–20]. Despite the growing awareness of sarcopenia, its prevalence remains high. Therefore, it is crucial to raise public awareness of sarcopenia and identify factors that can mitigate its impact.

Sarcopenia is closely related to unhealthy lifestyle habits. Daily sitting time is also a hot topic in lifestyle issues today. Based on existing research, we hypothesize that daily sitting time is correlated with sarcopenia. However, current research lacks large-scale population studies exploring this correlation and lacks robust theoretical support. This study uses data from the National Health and Nutrition Examination Survey (NHANES) survey from 2011 to 2018 to investigate the relationship between daily sitting time and sarcopenia, providing a scientific basis for identifying high-risk groups and developing preventive measures.

Method

Study population

This cross-sectional study used the publicly available NHANES dataset (http://www.cdc.gov/nchs/nhanes.htm), which is an ongoing national survey aimed at collecting health and nutrition information from the U.S. population. The survey was approved by the ethics review board of the National Center for Health Statistics (NCHS), so no additional ethical review was needed. In this study, we selected 39,156 individuals from four cycles between 2011 and 2018, and after applying strict inclusion criteria, we identified 9,998 participants, as detailed in Fig. 1. We excluded 14,505 participants due to missing daily sedentary time, 11,434 missing related sarcopenia data, and 3,219 missing covariate data.

Sitting time

Sedentary time is a key part of sedentary behavior and is gathered through self-reported questionnaires. Sitting time is defined as the "time spent sitting or reclining on a typical day," which includes time spent sitting or leaning while awake at work, home, or school. This encompasses time spent at a desk, socializing with friends (primarily referring to static social leisure activities such as those in cafes, cinemas, etc.), riding in cars, buses, or trains, reading, playing cards, watching TV, or using a computer. Based on previous research and population distribution, sitting time is categorized into four levels: less than 4 h (h) per day, 4 to ≤6 h per day, 6 to ≤9 h per day, and ≥9 h per day, with less than 4 h of sitting time per day considered the reference group [21].

Definition of Sarcopenia

The NHANES uses dual-energy X-ray absorptiometry (DXA) to quantify appendicular skeletal muscle mass (ASM). Due to the design principles of the NHANES database, individuals aged 60 and older are not eligible to participate in DXA. ASM is defined as the total lean soft tissue mass of the arms and legs. Sarcopenia is objectively defined using the sarcopenia index (ASM/BMI), with a cutoff of less than 0.789 for men and less than 0.512 for

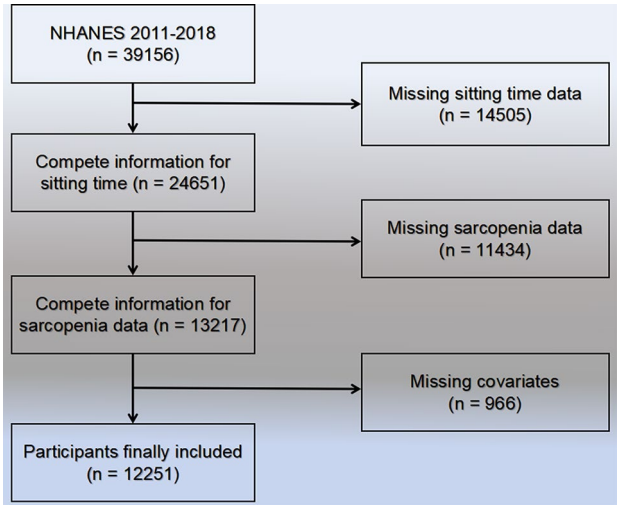

Fig. 1 Participant screening flowchart

women [22, 23], and previous studies have validated the feasibility of this criterion [24].

Covariates

The current study collected potential confounding variables that may associate sedentary time with sarcopenia based on previous research [24–26]. These covariates include age, gender, race, education level, poverty income ratio (PIR), height, weight, body mass index (BMI), waist circumference, smoking status, drinking status, diabetes, hypertension, coronary heart disease, moderate and vigorous recreational activity status, albumin, creatinine, blood urea nitrogen (BUN), high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), energy intake, protein intake, carbohydrate intake, and dietary fiber intake.

Smoking was defined as smoking 100 cigarettes or more during the life cycle; drinking was ever having 4–5 or more drinks a day. Chronic disease was based on physician diagnosis or medication records. Moderate leisure activities were ≥10 min/week of moderate-intensity exercise (e.g., brisk walking, cycling, swimming, golf); vigorous activities were ≥10 min/week of high-intensity exercise (e.g., running, basketball). Nutritional intake is calculated as the average of the first and second days.

Statistical analysis

NHANES uses complex sampling and weighting methods to represent the national population. The sample weight for this study is WTINT2YR/4. We used weighted chi-square tests and weighted linear regression to compare baseline characteristics. Results are presented as mean±standard error (SE; for continuous variables) or percentage (for categorical variables). Weighted logistic regression was used to analyze the relationship between sitting time and sarcopenia in different models, and trends were detected by grade (P values indicate trends (P for trends). Model 1 did not adjust for covariates, Model 2 adjusted for age, gender, race, education, and household income, while Model 3 made comprehensive adjustments for all covariates. In the fully adjusted model, we also employed generalized additive models (GAM) and smooth curve fitting to study their non-linear relationship. We conducted stratified analyses and interaction tests to assess the consistency and differences in outcomes among baseline variables. Furthermore, to further analyze the impact of vigorous activity on the relationship between the two, we employed chi-square tests and grouped logistic regression. All analyses were performed using R software version 4.1 and EmpowerStats version 4.1. P-values < 0.05 were considered statistically significant.

Results

The study ultimately included 9,998 participants with complete data (Fig. 1), which, when weighted, represent a total population of 104,887,159. The participants consisted of 5,166 females and 4,832 males, with over one-quarter spending 6 to ≤9 h sitting daily, and 60.05% of the total population sitting for more than 6 h (Table 1). There were significant differences in age, race, education level, PIR, activity status (vigorous and moderate activity), smoking status, drinking status, diabetes, coronary heart disease, and markers such as albumin, BUN, creatinine, TC, and LDL-C across different sedentary time groups. Sarcopenia prevalence rates were similar across the four groups, ranging from 6.93 to 7.81%.

We applied weighted univariate and multivariate logistic regression models to study the relationship between daily sitting time and sarcopenia, using individuals who sat < 4 h per day as the control group (Table 2). The unadjusted model (model 1) showed no significant association between sitting time and sarcopenia. However, after adjusting for demographic characteristics (model 2), groups with 6 to ≤9 h and ≥9 h per day of sitting time showed significant correlation with sarcopenia risk (6 to <9 h, OR = 1.40, 95% CI: 1.07–1.83; ≥ 9 h, OR = 1.63, 95% CI: 1.18–2.24), with longer sitting duration associated with higher risk(OR = 1.07, 95% CI: 1.02–1.11, $P = 0.0002$). The same trend was observed in the fully adjusted model (model 3), particularly showing significantly increased sarcopenia risk among individuals who sat for more than 6 h daily. Figure 2A shows the sarcopenia risk trend for different daily sedentary time groups in the fully adjusted model. Moreover, trend analysis indicated that sedentary time was significantly associated with the risk of sarcopenia (p for trend < 0.05), and this finding was confirmed in both preliminary and fully adjusted models.

Table 1 Participant characteristics by daily sitting time categories: NHANES 2011–2018, weighted

Variable	Sitting time/day (h)				
	< 4	**>=4, <6**	**>=6, <9**	**>=9**	***P*-value**
N (%)	1993 (19.93%)	2002 (20.02%)	3155 (31.56%)	2848 (28.49%)	
Age (years, mean ± SE)	38.88 ± 0.43	37.97 ± 0.53	35.28 ± 0.34	34.78 ± 0.43	< 0.0001
Gender (%)					0.6541
Male	48.76	47.67	50.18	48.86	
Female	51.24	52.33	49.82	51.14	
Race (%)					< 0.0001
Mexican American	16.71	11.80	9.23	7.58	
Other Hispanic	11.64	7.64	6.22	4.72	
Non-Hispanic white	51.40	61.28	63.24	67.09	
Non-Hispanic black	11.53	10.74	11.65	11.09	
Other Race	8.72	8.54	9.66	9.52	
Education level (%)					< 0.0001
Lower than 12th grade	19.08	15.03	10.51	6.66	
High school grade	28.80	24.70	20.29	15.46	
College graduate or above	52.12	60.27	69.20	77.88	
PIR (mean ± SE)	2.45 ± 0.07	2.73 ± 0.07	2.93 ± 0.07	3.37 ± 0.07	< 0.0001
BMI (kg/m2)	27.97 ± 0.17	27.83 ± 0.19	27.86 ± 0.18	28.09 ± 0.22	0.7029
Waist circumference (cm, mean ± SE)	95.95 ± 0.44	94.84 ± 0.45	94.94 ± 0.48	95.35 ± 0.56	0.8958
Vigorous activity (%)					< 0.0001
No	67.51	64.99	61.37	57.22	
Yes	32.49	35.01	38.63	42.78	
Moderate activity (%)					0.0197
No	49.35	50.26	52.16	46.29	
Yes	50.65	49.74	47.84	53.71	
Drinking status (%)					0.0030
No	84.74	86.14	88.71	88.48	
Yes	15.26	13.86	11.29	11.52	
Smoking status (%)					< 0.0001
No	58.85	59.80	65.70	66.82	
Yes	41.15	40.20	34.30	33.18	
Hypertension (%)					0.6589
No	30.29	28.34	28.80	28.13	
Yes	69.71	71.66	71.20	71.87	
Diabetes (%)					0.0068
No	93.95	95.48	94.41	96.37	
Yes	6.05	4.52	5.59	3.63	
Coronary heart disease (%)					0.0269
No	99.15	99.09	98.08	98.17	
Yes	0.85	0.91	1.92	1.83	
Sarcopenia (%)					0.8162
No	92.19	93.07	92.56	92.82	
Yes	7.81	6.93	7.44	7.18	
Albumin (g/L, mean ± SE)	42.86 ± 0.17	43.35 ± 0.12	43.59 ± 0.10	43.52 ± 0.11	0.0001
BUN (mg/dL, mean ± SE)	12.93 ± 0.14	12.66 ± 0.16	12.45 ± 0.10	12.60 ± 0.16	0.0299
Creatinine (mg/dL, mean ± SE)	0.82 ± 0.01	0.83 ± 0.01	0.84 ± 0.01	0.84 ± 0.01	0.0287
HDL-C (mg/dL, mean ± SE)	53.64 ± 0.55	53.272 ± 0.57	52.59 ± 0.44	52.46 ± 0.37	0.1457
TC (mg/dL, mean ± SE)	189.75 ± 1.37	189.48 ± 1.34	184.13 ± 1.10	184.42 ± 0.89	< 0.0001
TG (mg/dL, mean ± SE)	140.31 ± 3.39	138.70 ± 3.06	136.42 ± 2.72	142.56 ± 2.77	0.4403
LDL-C (mg/dL, mean ± SE)	110.93 ± 1.24	110.74 ± 1.25	106.77 ± 0.82	106.27 ± 0.80	0.0008
Intake of energy (kcal/d)	2114.53 ± 28.33	2177.22 ± 27.40	2103.17 ± 20.99	2103.60 ± 19.55	0.0995
Intake of protein (gm/d)	81.57 ± 1.18	84.41 ± 1.10	82.65 ± 0.93	83.20 ± 1.09	0.3447

Table 1 (continued)

Variable	Sitting time/day (h)				
	< 4	>=4, <6	>=6, <9	>=9	*P*-value
Intake of carbohydrate (gm/d)	254.87 ± 3.17	259.05 ± 3.76	250.05 ± 2.77	248.65 ± 2.80	0.1474
Intake of dietary fiber (gm/d)	17.10 ± 0.39	17.19 ± 0.31	16.52 ± 0.24	17.02 ± 0.31	0.1918

Mean ± SE for continuous variables and P value was calculated by weighted linear regression model. % for Categorical variables and P value was calculated by weighted chi-square test. $P < 0.05$ presents significant difference. SE, standard error; PIR, the ratio of family income to poverty; BMI, body mass index; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; BUN, blood urea nitrogen

Table 2 Univariate and multivariate analyses by logistic regression model, weighted

	Model 1 OR (95%CI) *P*-value	Model 2 OR (95%CI) *P*-value	Model 3 OR (95%CI) *P*-value
Sitting time/day (h)	1.01 (0.98, 1.05) 0.5145	1.07 (1.02, 1.11) 0.0002	1.07 (1.03, 1.10) 0.0010
Group (h)			
< 4	Ref.	Ref.	Ref.
>=4, <6	0.88 (0.69, 1.11) 0.2859	1.08 (0.86, 1.36) 0.5187	1.26 (0.98, 1.61) 0.0834
>=6, <9	0.95 (0.72, 1.24) 0.7028	1.40 (1.07, 1.83) 0.0180	1.57 (1.18, 2.10) 0.0045
>=9	0.91 (0.67, 1.24) 0.5570	1.63 (1.18, 2.24) 0.0042	1.74 (1.22, 2.47) 0.0043
P for trend	0.98 (0.89, 1.09) 0.7295	1.19 (1.07, 1.32) 0.0023	1.20 (1.07, 1.35) 0.0031

Model 1: adjusted for none

Model 2: adjusted for age, gender, race, education level, PIR

Model 3: adjusted for age, gender, race, education level, PIR, BMI, waist circumference, albumin, vigorous activity, moderate activity, drinking status, smoking status, hypertension, diabetes, coronary heart disease, BUN, TC, TG, HDL-C, LDL-C, creatinine, intake of energy, intake of protein, intake of carbohydrate, intake of dietary fiber. $P < 0.05$ presents significant difference

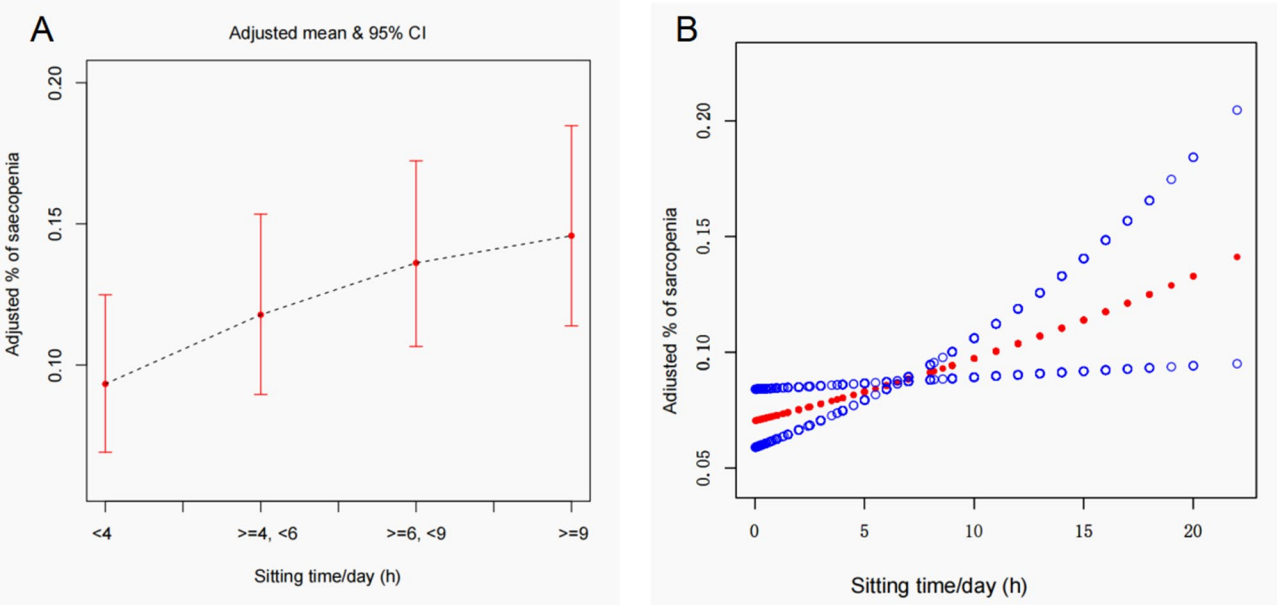

Fig. 2 The correlation between daily sitting time and sarcopenia. **A**: Adjusted prevalence of sarcopenia and its 95% confidence interval (CI) for different sedentary time groups. **B**: The red line represents the smooth fitting curve between variables, and the blue band indicates the 95% CI of the fit. (Adjustments have been made for all relevant covariates)

GAM and smooth curve fitting analyses indicated a linear relationship between sitting time and sarcopenia (Fig. 2B), with each unit increase in sitting time associated with a 7% increased risk of sarcopenia. Weighted stratification and interaction effect analyses identified potential factors influencing this relationship, with results showing that gender, race, and BMI may play a role (Table 3). Notably, males, non-Hispanic whites, and individuals with a BMI of less than 25 may face a higher risk of sarcopenia.

Further analysis of the relationship between vigorous recreational activities and sarcopenia showed that individuals who participated in vigorous recreational activities had lower rates of sarcopenia, regardless of their daily sitting time (Fig. 3). Significant differences in sarcopenia prevalence were observed between those who

Table 3 Stratified analysis and interaction analysis, weighted. Each stratification adjusted for all factors except the stratification factor itself

Characteristics	Sitting time/day (h)					
	N **(Sarcopenia)**	**< 4 (OR, 95% CI)**	**>=4, < 6 (OR, 95% CI)**	**>=6, < 9 (OR, 95% CI)**	**>=9 (OR, 95% CI)**	***P*-for interaction**
N (Sarcopenia)	12,251 (1071)	2520 (244)	2507 (222)	3823 (336)	3401 (269)	
Age						0.2115
<40	7019 (535)	Ref.	1.62 (1.10, 2.38)	1.72 (1.18, 2.52)	2.17 (1.45, 3.25)	
>=40	4161 (536)	Ref.	1.14 (0.66, 1.99)	1.64 (1.06, 2.53)	1.58 (0.96, 2.62)	
Gender (%)						0.0203*
Male	5459 (624)	Ref.	1.38 (0.90, 2.11)	1.51 (0.99, 2.26)	2.34 (1.11, 1.54)	
Female	5721 (447)	Ref.	1.06 (0.71, 1.57)	1.50 (0.94, 2.43)	0.94 (0.59, 1.48)	
Race						0.0007*
Mexican American	1693 (378)	Ref.	0.95 (0.64, 1.41)	1.09 (0.74, 1.59)	0.99 (0.62, 1.57)	
Other Hispanic	1134 (165)	Ref.	0.72 (0.36, 1.47)	1.21 (0.71, 2.07)	1.73 (0.91, 3.26)	
Non-Hispanic white	3752 (287)	Ref.	2.17 (1.12, 4.20)	2.83 (1.34, 6.01)	3.19 (1.40, 7.26)	
Non-Hispanic black	2520 (68)	Ref.	4.04 (0.98, 13.12)	5.69 (2.01, 16.09)	3.14 (0.96, 10.25)	
Other Race	2081 (173)	Ref.	1.15 (0.40, 3.28)	0.77 (0.33, 1.80)	1.16 (0.53, 2.54)	
Education level (%)						0.2637
Lower than 12th grade	1914 (339)	Ref.	0.96 (0.66, 1.42)	1.83 (1.13, 2.96)	1.53 (0.90, 2.60)	
High school grade	2469 (284)	Ref.	1.20 (0.71, 2.01)	1.02 (0.59, 1.77)	1.44 (0.83, 2.52)	
College graduate or above	6797 (448)	Ref.	1.64 (0.98, 2.74)	2.12 (1.19, 3.76)	2.25 (1.30, 3.90)	
PIR						0.8307
< 1.3	3761 (441)	Ref.	1.34 (0.94, 2.09)	1.48 (1.07, 2.23)	1.48 (0.96, 2.29)	
>= 1.3, < 3.5	4185 (406)	Ref.	0.97 (0.64, 1.46)	1.21 (0.79, 1.87)	1.55 (0.89, 2.72)	
>= 3.5	3234 (224)	Ref.	1.37 (0.65, 2.78)	1.70 (0.77, 3.96)	1.79 (0.88, 3.73)	
BMI						0.0067*
< 25	4567 (180)	Ref.	3.48 (1.39, 8.75)	5.98 (2.58, 13.85)	7.16 (2.81, 18.27)	
>=25, < 30	3321 (247)	Ref.	1.17 (0.67, 2.05)	1.57 (0.97, 2.55)	1.27 (0.69, 2.34)	
>=30	3292 (644)	Ref.	1.10 (0.83, 1.45)	1.14 (0.79, 1.64)	1.47 (0.94, 2.28)	
Drinker status (%)						0.9651
No	9839 (911)	Ref.	1.18 (0.93, 1.50)	1.43 (1.05, 1.95)	1.58 (1.08, 2.30)	
Yes	1341 (160)	Ref.	1.16 (0.46, 2.96)	1.40 (0.70, 2.80)	1.87 (0.91, 3.86)	
Smoking status (%)						0.0577
No	7338 (708)	Ref.	1.12 (0.82, 1.55)	1.46 (0.99, 2.16)	1.28 (0.90, 1.81)	
Yes	3842 (363)	Ref.	1.28 (0.75, 2.16)	1.34 (0.84, 2.12)	2.41 (1.37, 4.22)	
Hypertension (%)						0.1126
No	3452 (311)	Ref.	1.67 (1.03, 2.71)	1.61 (1.07, 2.43)	1.41 (0.82, 2.43)	
Yes	7728 (760)	Ref.	0.99 (0.73, 1.36)	1.36 (0.95, 1.94)	1.67 (1.10, 2.52)	
Diabetes (%)						0.9024
No	10,597 (934)	Ref.	1.19 (0.92, 1.54)	1.43 (1.05, 1.95	1.58 (1.10, 2.27)	
Yes	583 (137)	Ref.	1.11 (0.59, 2.07)	1.39 (0.64, 3.05)	2.16 (1.03, 4.52)	
Coronary heart disease (%)						0.2310
No	11,003 (1048)	Ref.	1.13 (0.88, 1.45)	1.44 (1.10, 1.90)	1.61 (1.12, 2.30)	
Yes	177 (23)	Ref.	18.10 (0.93, 353.55)	1.34 (0.09, 20.37)	3.98 (0.34, 46.06)	
Vigorous activity (%)						0.7055
No	6796 (801)	Ref.	1.08 (0.78, 1.51)	1.33 (0.99, 1.79)	1.53 (1.04, 2.26)	
Yes	4384 (270)	Ref.	1.63 (0.82, 3.24)	1.86 (1.07, 3.23)	2.02 (1.20, 3.40)	
Moderate activity (%)						0.9024
No	5909 (667)	Ref.	1.17 (0.79, 1.75)	1.44 (0.98, 2.12)	1.52 (0.96, 2.41)	
Yes	5271 (404)	Ref.	1.18 (0.74, 1.88)	1.40 (0.96, 2.05)	1.76 (1.10, 2.81)	

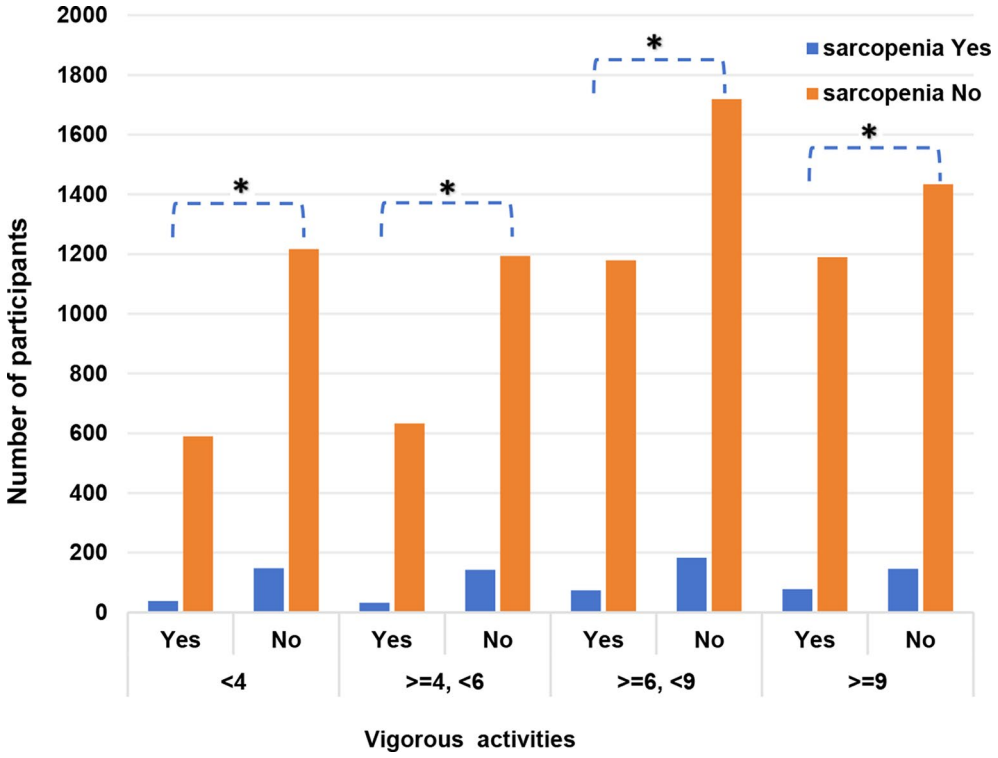

Fig. 3 Effects of vigorous activity on sarcopenia prevalence. *, $P < 0.05$

participated in vigorous activities and those who did not across all groups (Supplementary Table 1). According to the grouped logistic regression model (Model 3) fully adjusted for covariates, individuals lacking vigorous activity showed a statistically significantly higher risk of developing sarcopenia compared to those with vigorous activity (Supplementary Table 2). Non-linear analysis further confirmed that among people lacking vigorous activities, sitting time showed a linear relationship with sarcopenia, with longer sitting times associated with higher risk (Supplementary Fig. 1).

Discussion

This study aims to evaluate the relationship between daily sitting time and sarcopenia, and to examine the impact of vigorous recreational activities. In a cross-sectional analysis of 9,998 participants (weighted represent approximately 10.48 million individuals), it was found that over 60% of participants sat for >6 h daily, particularly non-Hispanic whites with higher educational levels. Through weighted logistic regression analysis, we discovered a positive correlation between sedentary time and the risk of sarcopenia, especially after adjusting for covariates; individuals had a significantly increased risk of sarcopenia. GAM and smooth curve analyses further confirmed this linear relationship, showing that for each additional hour of sedentary time, the risk of sarcopenia increased by 7%. Notably, males, non-Hispanic whites, and individuals with a BMI of less than 25 may face a higher risk of sarcopenia. Our research found that for each additional hour of daily sitting time, the risk of sarcopenia increases by 7%. Although this single increment may seem small, its cumulative effect cannot be overlooked, especially for populations lacking physical activity. This study provides important scientific evidence for understanding the potential threats of modern lifestyles to muscle health.

With the development of society, modern lifestyles and work habits have undergone significant changes, and prolonged sitting has become an important part of daily life [27, 28]. Reports show that Australian adults spend 50–70% of their day in a sedentary state [29], while American adults have increased their total sitting time by nearly one hour over the past decade [30]. This sedentary and inactive lifestyle has increased various health risks, including obesity, cardiovascular diseases, diabetes, mental health issues, musculoskeletal disorders, and mortality rates [2, 3, 31–33]. Research indicates that increased sitting time is closely associated with all-cause mortality and cognitive decline in older adults [34, 35]. Furthermore, sedentary behavior significantly raises healthcare costs, with the medical expenses in Australia attributed to sedentary behavior reaching AUD 185 million [36], while in the UK, it is as high as GBP 800 million [37]. According to a recent report from The Lancet, nearly one-third of adults do not meet the World Health

Organization (WHO) recommended levels of physical activity, with the age-standardized prevalence of physical inactivity reaching 31.3% [38]. In 2020, the WHO guidelines for the first time recommended reducing sedentary behavior, emphasizing the substantial health benefits of increasing physical activity [6].

In recent years, sarcopenia has become a major public health concern. Sarcopenia, a term coined by Irwin Rosenberg, describes age-related muscle atrophy [39]. It is now defined as a disease characterized by a reduction in skeletal muscle mass, strength, and function [21]. Approximately 10-16% of the elderly population worldwide are affected by this condition [8]. Sarcopenia leads to a decline in functional capacity and quality of life during the aging process, and increases the risk of adverse outcomes such as falls, disability, frailty, hospitalization, and all-cause mortality [10, 21, 40]. Sarcopenia primarily affects the elderly, but it is gradually spreading to younger individuals. With the global increase in the elderly population, the prevalence of sarcopenia is expected to rise, posing a significant burden on public health systems. As there is currently no cure, the prevention or slowing of sarcopenia progression is of utmost importance.

Prolonged sitting is often seen as a sign of physical inactivity, but research shows that even with regular exercise, prolonged sitting is still harmful to metabolic health [41]. This suggests that the impact of prolonged sitting on health is partly independent of exercise, and the detrimental association between sitting time and various diseases cannot be fully mitigated or eliminated through exercise alone [42]. Despite previous studies exploring the potential impact of sedentary behavior on sarcopenia [43], there is a lack of sufficient evidence and large-scale population research. Our research shows that prolonged sitting time is significantly associated with the risk of sarcopenia, and the longer the sitting time, the higher the risk of sarcopenia. Furthermore, the prevalence and risk of sarcopenia are higher in populations lacking vigorous recreational activities. Notably, in populations engaging in vigorous recreational activities, the impact of sedentary behavior on sarcopenia is not significant. Therefore, we strongly recommend that people who sit for long periods of time each day increase their physical activity to prevent sarcopenia.

Several biological mechanisms may explain our results. First, prolonged sedentary behavior may reduce muscle protein synthesis by lowering the sensitivity of muscle anabolic metabolism, leading to muscle loss and a decline in physical function [44]. Second, sedentary behavior may increase levels of chronic low-grade inflammation [45], stimulating protein catabolism and inhibiting muscle synthesis [46]. Additionally, factors such as malnutrition, insulin resistance, mitochondrial dysfunction, oxidative stress, declining motor neuron function, and aging are also considered potential causes [7, 47–49].

Previous research has suggested that hormonal changes during menopause in women lead to a higher morbidity rate compared to men [50, 51]. However, in our study, the average age of the subjects was 34–39 years, during which estrogen plays a protective role for women. The results indicated that the morbidity rate was higher in men, a finding that is supported by Patel HP et al. [52]. Although obesity has many negative effects on health, our research found that a lower body mass index is significantly associated with the risk of sarcopenia, consistent with previous studies [53]. Furthermore, sarcopenia also shows variability across different regions and ethnicities, with differences observed between Western and Asian populations, as well as between White and Black individuals [54].

This study has several advantages. First, it is a large-scale cross-sectional study, benefiting from the rigor of the NHANES data, making the results relatively reliable. Secondly, by adjusting for covariates using different data models, potential confounding factors were effectively controlled. However, the study also has its limitations. First, the cross-sectional design makes it difficult to establish causal relationships. Second, the exposure variables rely on self-reporting, which may introduce bias and affect the analysis results. Additionally, DXA can only assess populations under 60 years old, leading to a lack of research on elderly patients. Therefore, future research should be more comprehensive and in-depth to further validate these findings.

Conclusion

Our research shows that after adjusting for potential confounding factors, sedentary time is significantly associated with sarcopenia, and the risk of sarcopenia increases with longer daily sitting time. This association is more pronounced in non-Hispanic white men with a BMI less than 25. Furthermore, those without vigorous recreational activity have a higher prevalence and risk of sarcopenia compared to those with vigorous recreational activity. Therefore, reducing sedentary behavior and increasing moderate exercise may effectively prevent sarcopenia.

Abbreviations

NHANES	National Health and Nutrition Examination Survey
BMI	Body mass index
ASM	Appendicular skeletal muscle mass
NCHS	National Center for Health Statistics
DXA	Dual-energy X-ray absorptiometry
PIR	Poverty income ratio
BUN	Blood urea nitrogen
HDL-C	High-density lipoprotein cholesterol
TC	Total cholesterol
TG	Triglycerides
LDL-C	Low-density lipoprotein cholesterol

SE Standard error
GAM Generalized additive models

Supplementary Information

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Supplementary Material 1

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Author contributions
TT and ALZ contributed to the conception and design of the study; YLI, JLZ, YZ, SGX, HYS, and TXZ were responsible for data collection and processing; TT, ALZ, TXZ, and YLI performed the data analyses and constructive discussions. TT and ALZ drafted the manuscript, tables, and figures, and other authors critically revised the manuscript. All authors contributed to the article and approved the submitted version.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval
The NHANES data is publicly available. According to local laws and institutional requirements, this study did not require ethical review and approval.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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