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## Ideal cardiovascular health metrics: Are they just cardiovascular protective factors?

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## Ideal cardiovascular health metrics: Are they just cardiovascular protective factors?

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## Abstract

**Objective:** The American Heart Association (AHA) proposed the concept of ideal cardiovascular health (CVH) to reduce the risk of cardiovascular mortality. We attempted to broaden the impact of CVH and further contribute to AHA 2030 goals by identifying the relationship between CVH and non-cardiovascular diseases such as sarcopenia.

**Design:** Cross-sectional survey

**Setting:** National Health and Nutrition Examination Survey conducted in the USA from 2011 to 2018.

**Participants:** This study included participants with reliable first 24-h dietary recall and  $\geq 20$  years of age and excluded those could not diagnosis sarcopenia or insufficient data to calculate the CVH scores.

**Primary and secondary outcome measures:** The prevalence of sarcopenia and measured by dual-energy X-ray absorptiometry.

**Results:** This cohort study involving 3,311 adults  $> 20$  years comprised 1,329 females (42.41%). The number of intermediate or ideal and poor CVH participants was 1,719 and 1,592 with mean CVH score of  $9.32 \pm 0.06$  and  $5.43 \pm 0.05$ , respectively. After adjusting for related confounding factors, intermediate or ideal CVH was associated with a risk reduction of sarcopenia than poor CVH (adjusted odds ratio [aOR]: 0.39, 95% CI: 0.22-0.69,  $P < 0.001$ ) and the risk of sarcopenia was significantly lower for each incremental increase of 1 in CVH metrics (aOR: 0.76, 95% CI: 0.70-0.83,  $P < 0.001$ ). Moreover, if the number of ideal CVH metrics was  $> 5$ , the risk of sarcopenia decreased by up to 85% (aOR: 0.15, 95% CI: 0.06-0.38,  $P < 0.001$ ).

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5 **Conclusions:** Our findings suggest a relationship between the CVH and the prevalence of sarcopenia in adults. The results of our study can  
6  
7 contribute to achieving the 2030 public health goal of achieving CVH for all, which may be supported by efforts to reduce the prevalence of  
8  
9 sarcopenia.  
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11 **Keywords:** cardiovascular health metrics, sarcopenia, NHANES  
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#### 14 15 16 **Strengths and limitations of this study** 17

18 This study benefited from the large, nationally representative data set and rigorous research methods of the National Health and Nutrition  
19  
20 Examination Survey.  
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23 This study suggests a relationship between the CVH and the prevalence of non-cardiovascular disease, sarcopenia. The results of our study  
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25 can help facilitate the 2030 goal of achieving CVH for all because the AHA 2030 goal may be supported by efforts to reduce the prevalence of  
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27 sarcopenia.  
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30 The limitations of this study were that data were derived from cross-sectional studies and that the relationship was not necessarily identified  
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32 as causal.  
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35 Use of self-reported data might result in recall bias.  
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## Introduction

Life expectancy in the United States has been stagnant since 2010 which has been attributed to a lack of progress in cardiovascular disease mortality. [1] Indeed, cardiovascular disease (CVD) remains the primary cause of mortality globally and a huge burden on public health expenditure. [2] Previous investigators have used the Framingham and SCORE risk estimation systems to assess a patient's risk for CVD. [3, 4]

These risk scores are primarily derived from the development and establishment of effective primary and secondary prevention interventions for high-risk populations. However, individuals with significantly elevated levels of risk factors are relatively uncommon in the population. Most CVD and stroke events occur in individuals with average or only slightly unfavorable levels of risk factors. Therefore, the concept of cardiovascular health (CVH) was introduced to reduce the risk of cardiovascular mortality in 2010. [5] CVH includes seven metrics, including body mass index (BMI), cigarette smoking, physical activity, dietary intake, total cholesterol level, blood pressure, and fasting glucose level. [5] The beneficial effects of ideal CVH metrics are widely supported by mounts of scientific research. [6] However, a recent study showed that the prevalence of ideal CVH status is low on some metrics, such as dietary pattern. [7] Moreover, a study involving the offspring of Framingham participants showed that the decreasing presence of ideal CVH metrics over the past 20 years has resulted in increasing risks of subclinical diseases, CVDs, and death. [8] Therefore, there is a long way to go regarding the "Strategic Impact Goals for 2030 and Beyond" issued by the American Heart Association (AHA).

Previous studies have suggested that an ideal CVH is negatively associated with age-related diseases. [9] Sarcopenia, marked by the age-



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5 related loss of muscle mass, strength, and function, has become a severe medical problem in the current aging society. A meta-analysis indicated  
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7 that patients with sarcopenia have decreased function, and higher rates of falls and hospitalization. [10] Sarcopenia shares many common  
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9 pathogenic mechanisms with CVDs, such as hormonal changes, inflammation and oxidative stress. [11] Studies have confirmed that sarcopenia  
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11 is significantly associated with increased cardiovascular events or mortality, [12] and patients with CVDs are also more likely to develop  
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13 sarcopenia than age-matched controls. [13]

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16 Although several studies have explored the relationship between cardiovascular risk factors and sarcopenia, [14] it remains unclear whether  
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18 ideal CVH metrics are beneficial in sarcopenic populations.

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21 This study aimed to determine the relationship between CVH and sarcopenia by using the 2011-2018 National Health and Nutrition  
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23 Examination Survey (NHANES) data to contribute to the accomplishment of the AHA 2030 goals.

## 24 25 26 27 28 29 **Methods**

### 30 31 **Patient and public involvement**

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33 We conducted a retrospective analysis of a cohort of US population of the NHANES, a periodic survey performed by National Center for Health  
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35 Statistics. Informed consent has been obtained from every participant and therefore there was no need for any ethical consent in this study. The  
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37 NHANES includes extensive demographic data, physical examinations, laboratory tests, health-related questionnaires and lists of prescription  
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5 medications. As shown in **Figure 1**, this study included participants with reliable first 24-h dietary recall and  $\geq 20$  years of age during NHANES  
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7 2011-2018 (n = 21128). Of these participants, 17817 were excluded based on the following: (i) CVD (myocardial infarction, congestive heart  
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9 failure, and stroke) and cancer; (ii) insufficient data to calculate the CVH scores; and (iii) no reliable dual-energy X-ray absorptiometry (DXA)  
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11 and body mass index (BMI) data. Thus, 3311 participants were enrolled in the present study.  
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### 16 **DXA, appendicular skeletal muscle mass, and the definition of sarcopenia**

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18 DXA whole-body scans were performed on participants 8-59 years of age using Hologic Discovery model A densitometers (Hologic, Inc.,  
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20 Bedford, MA, USA). DXA exclusion criteria included pregnancy, weight  $>300$  pounds (136 kg, because of the weight limit of the scanner),  
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22 height  $> 6'5''$  (DXA table limitations), history of radiographic contrast material (barium) used in the past 7 days, or nuclear medicine studies in  
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24 the past 3 days. Hologic software (version 8.26: a3\*) was used to administer all scans.  
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28 Appendicular skeletal muscle mass was measured using DXA. The sarcopenia index was calculated as follows: sarcopenia index = total  
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30 appendicular skeletal muscle mass (in kg)/BMI ( $\text{kg}/\text{m}^2$ ).  
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33 Sarcopenia was defined as the lowest for sex-specific sarcopenia index cut-off values (0.789 for men and 0.512 for women), based on the  
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35 National Institutes of Health (FNIH).  
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**CVH metrics**

CVH metrics include four health behaviors (cigarette smoking, physical activity, healthy dietary scores, and BMI) and three health factors (total cholesterol level, blood pressure, and fasting plasma glucose level). [5]. The definitions of ideal, intermediate, and poor CVH metrics for adults are presented in **Table 1**. We used the Healthy Eating Index 2010 (HEI-2010) scores as a proxy of healthy dietary scores, which were calculated using first-day 24-h dietary recall. HEI-2010 scores were based on a 12-component index, with total scores ranging from 0-100, and a higher score indicating a healthier diet: total fruit; whole fruit; total vegetables; grains and beans; whole grains; dairy; total protein foods; seafood and plant protein; fatty acids; refined grains; sodium; and empty calories. Participants with an HEI-2010 score  $\leq 50$  were assigned to poor health, those with a score of 51-80 to intermediate health, and those with a score  $\geq 81$  to ideal health.

**Table 1. Distribution of ideal, intermediate and poor CVH for each metric for adults free of CVD, NHANES 2011-2018**

<b>AHA definitions of CVH for each metric</b>		<b>Total sample (n=3,311)</b>
<b>Smoking status, n (%)</b>		
Ideal	Never or quit > 12 months ago	1212 (40.1)
Intermediate	Former $\leq 12$ months	202 (7.2)
Poor	Current smoking	1897 (52.8)
<b>Body mass index, n (%)</b>		
Ideal	< 25 kg/m <sup>2</sup>	1025 (30.3)
Intermediate	25-29.9 kg/m <sup>2</sup>	1080 (33.8)
Poor	$\geq 30$ kg/m <sup>2</sup>	1206 (35.8)

**Physical activity, n (%)**

Ideal	≥ 150 min/week moderate or ≥ 75 min/week vigorous or ≥ 150 min/week moderate + vigorous	1553 (48.1)
Intermediate	1-149 min/week moderate or 1-74 min /week vigorous or 1-149 min/week moderate + vigorous	218 (7.4)
Poor	None	1540 (44.5)

**Healthy diet score<sup>\*</sup>, n (%)**

Ideal	4-5 components	42 (1.7)
Intermediate	2-3 components	1199 (37.9)
Poor	0-1 components	2070 (60.4)

**Total cholesterol, n (%)**

Ideal	< 200 mg/dL	1751 (49.8)
Intermediate	200-239 mg/dL or treated to goal	925 (30.3)
Poor	≥ 240 mg/dL	635 (20.0)

**Blood pressure, n (%)**

Ideal	SBP < 120 or DBP < 80 mmHg	1459 (45.2)
Intermediate	SBP 120-139 or DBP 80-89 mmHg or treated to goal	1180 (33.6)
Poor	SBP ≥ 140 or DBP ≥ 90 mmHg	744 (21.2)

**Fasting plasma glucose, n (%)**

Ideal	< 100 mg/dL	2282 (75.8)
Intermediate	100-125 mg/dL or treated to goal	713 (16.7)
Poor	≥ 126 mg/dL	316 (7.6)

**Abbreviation:** CVH, cardiovascular health; CVD, cardiovascular disease; NHANES, National Health and Nutrition Examination Survey; AHA, The American Heart Association; DBP, diastolic blood pressure; SBP, systolic blood pressure.

\* AHA's healthy diet score includes five components: fruits and vegetables, whole grain, fish, sodium, and sugar-sweetened beverage, and a very small proportion (<0.5%) of U.S. adults meet the ideal healthy diet. HEI-2010 is a continuous score consisting of 12 components representing major food groups including fruit and vegetables, whole grains, proteins, dairy, oils, sodium, and empty calories. HEI-2010 score ranges from 0 to 100 with a higher score indicates more healthy diet. HEI-2010 has been validated to represent the diet quality in population. We used HEI-2010 as a proxy for AHA's healthy diet score with ideal diet: HEI-2010 ≥ 81;

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5 intermediate diet: 51-80; and poor diet:  $\leq 50$ .

6 To maximize the sample size, we used hemoglobin A1c (HbA1c) values  $< 5.7\%$ ,  $5.7\%-6.4\%$ , and  $\geq 6.5\%$  as a proxy for fasting plasma  
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8 glucose levels  $< 100$  mg/dL,  $100$  to  $< 126$  mg/dL, and  $\geq 126$  mg/dL, respectively, as recommended by the American Diabetes Association.  
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10 Participants who reported having diabetes or being treated with insulin or an oral medication to lower blood glucose and had an HbA1c  
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12 concentration between  $5.7\%$  and  $6.4\%$  were categorized as intermediate health. Similarly, participants who reported taking cholesterol-lowering  
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14 or antihypertensive medications and were treated to goal were categorized as “intermediate,” whereas participants with these conditions who  
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16 were untreated or who were not treated to goal were categorized as “poor” for that health factor. Use of antihypertensive, cholesterol-lowering,  
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18 and glucose-lowering medications were self-reported. Total cholesterol and plasma glucose levels were measured with enzymatic methods  
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20 (<https://www.cdc.gov/nchs/nhanes/index.htm>). BMI was calculated as the weight in kilograms divided by the height in meters squared. The  
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22 mean blood pressure was estimated from up to three readings obtained under standard conditions during a single physical examination.  
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26 For each metric, participants received 0, 1, or 2 points, representing poor, intermediate, or ideal categories, respectively. Participants with  
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28 overall scores of 0-7, 8-11, or 12-14 points were categorized as having poor, intermediate, or ideal CVH, respectively. Owing to the relatively  
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30 low number of people with an ideal CVH score in this sample, the intermediate and ideal CVH categories were combined.  
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### 35 36 **Statistical analysis**

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38 We used the NHANES recommended weights to account for planned oversampling of specific groups. The continuous variables were expressed  
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5 as the mean  $\pm$  standard deviation, and the categorical variables were presented as counts (percentages). Baseline characteristics between the two  
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7 CVH groups were compared using a t-test for continuous variables and a  $\chi^2$  test for categorical variables.  
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10 Multiple logistic regression was used to examine the independent influence of CVH on sarcopenia comparing poor CVH versus intermediate  
11 or ideal CVH after adjustments for potential confounders, such as age, sex, and race/ethnicity, educational level and alcohol. The odds ratio (OR)  
12 and 95% confidence interval (CI) were computed. We explored the relationship between CVH and sarcopenia in different subgroups (age, sex,  
13 race/ethnicity, education level and alcohol use). We also separately estimated the association between individual components of the CVH  
14 metrics and sarcopenia. When assessing the role of individual components, the age, sex, race/ethnicity, and education level were adjusted.  
15  
16 Furthermore, we used multiple logistic regression analysis to assess the effect of a different number of ideal cardiovascular health metrics  
17 (ICVHMs) on the incidence of sarcopenia. A two-sided *P*-value  $< 0.05$  indicated significance for all analyses. All data analyses were performed  
18 using SAS Release 9.4 (SAS Institute) and Survey package in R software (version 4.0.4; R Foundation for Statistical Computing, Vienna,  
19 Austria).  
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## 33 **Results**

### 34 **Baseline characteristics**

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38 This study shown that only 1.7% of the participants met the ideal diet criteria. The prevalence of participants meeting the ideal level for the  
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5 remainder of CVH metrics were cigarette smoking (40.1%), diabetes (75.8%), total cholesterol level (49.8%), blood pressure (45.2%), physical  
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7 activity (44.5%), and BMI (30.3%) (**Table 1**).

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9 This cohort study involved 3311 adults  $\geq 20$  years of age, comprising 1329 females (weighted proportion, 42.4%) and 1982 males  
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11 (weighted, 47.6%), with a weighted mean (SE) age of  $40.0 \pm 0.4$  years. 1477 (weighted, 66.6%) were of non-Hispanic white ancestry, 753  
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13 (weighted, 15.7%) of Hispanic ancestry, and 618 (weighted, 9.6%) of non-Hispanic Black ancestry. The study population characteristics are  
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15 listed in **Table 2** by CVH metrics. The number of intermediate or ideal and CVH participants was 1719 and 1592, with mean CVH metrics of  
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17  $9.3 \pm 0.1$  and  $5.4 \pm 0.1$ , respectively. The differences of CVH metrics were significant for age, race/ethnicity, and education ( $P < 0.001$ ). The  
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19 prevalence of sarcopenia in participants with poor CVH metrics was 9.9%, more than two times as participants with intermediate or ideal CVH  
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21 metrics (3.6%).  
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28 **Table 2. Baseline characteristics of the study population**

Characteristics	Total (n=3311)	Intermediate or Ideal CVH (n=1719)	Poor CVH (n=1592)	P value
Age, mean (SE), years	40.0 (0.4)	37.3 (0.5)	42.9 (0.4)	< 0.001
Female, n (%)	1329 (42.4)	614 (41.5)	715 (43.5)	0.382
Race/ethnicity, n (%)				
Hispanic	753 (15.7)	362 (15.3)	391(16.0)	
Non-Hispanic Black	618 (9.6)	232 (7.2)	386 (12.4)	< 0.001
Non-Hispanic White	1477 (66.6)	760 (69.8)	717 (63.0)	

Other	463 (8.1)	238 (7.7)	225 (8.6)	
<b>Heavy use of alcohol, n (%) *</b>				
< 12	2558 (96.4)	1273 (97.4)	1285 (95.1)	
≥ 12	103 (3.6)	40 (2.6)	63 (4.9)	0.062
<b>Education levels, n (%)</b>				
< 12	1645 (44.9)	735 (41.8)	910 (48.3)	
12	1135 (35.7)	543 (35.5)	592 (36.0)	0.005
> 12	530 (19.4)	313 (22.7)	217 (15.8)	
<b>Scores of CVH metrics, mean (SE)</b>	7.49 (0.1)	9.32 (0.1)	5.43 (0.1)	< 0.001
<b>Sarcopenia, n (%)</b>				
Yes	247 (6.6)	67 (3.6)	180 (9.9)	
No	3064 (94.4)	1525 (96.4)	1539 (90.1)	< 0.001

**Abbreviation:** CVH, cardiovascular health.

\* Data missing > 5%

### Association between CVH metrics and sarcopenia

After adjusting for age, sex, race/ethnicity, education level, and alcohol use, intermediate or ideal CVH was associated with a risk reduction of sarcopenia than poor CVH (adjusted odds ratio [aOR]: 0.39, 95% CI: 0.22-0.69,  $P < 0.001$ ; **Table 3**). In the fully adjusted model, the risk of sarcopenia was significantly lower for each incremental increase of 1 in CVH metrics (aOR: 0.76, 95% CI: 0.70-0.83,  $P < 0.001$ ). Further stratified and interaction analyses were performed for age, sex, race/ethnicity, and education level. The association between intermediate or ideal CVH and sarcopenia was not significant in female and lower education level subgroups. Further, the effect of different ages was explored in the female subgroup. In the female participants < 45 years of age, intermediate or ideal CVH scores remained an independent protective factor for



sarcopenia (aOR: 0.14, 95% CI: 0.05-0.40,  $P < 0.001$ ; **Table S1**). Among subgroups of non-Hispanic Black and other ancestry, the risk of sarcopenia decreased by 75% in participants with intermediate or ideal CVH than in participants with poor CVH (aOR: 0.25, 95% CI: 0.07-0.88,  $P = 0.038$ ; aOR: 0.24, 95%CI: 0.09-0.66,  $P = 0.008$ ; Table 3).

**Table 3. The association between CVH metrics and Sarcopenia by selected subgroups**

Variable	No. (%)	Intermediate or Ideal CVH OR (95%CI) *	P value	P for interaction
<b>Continuous</b>				
CVH (per 1 score)	247/3311	0.76 (0.70-0.83)	<0.001	-
<b>Categories †</b>				
Poor CVH	180/1719	1[Ref]	-	-
Intermediate or Ideal CVH	67/1592	0.39 (0.22-0.69)	<0.001	-
<b>Subgroup</b>				
<b>Age</b>				
<45	112/2024	0.35 (0.20-0.64)	<0.001	0.858
45-59	135/1287	0.40 (0.16-1.04)	0.067	
<b>Sex</b>				
Male	158/1982	0.43 (0.23-0.82)	0.014	0.539

Female	89/1329	0.30 (0.07-1.32)	0.117	
<b>Race</b>				
Hispanic	126/753	0.42 (0.23-0.77)	0.007	
Non-Hispanic Black	17/618	0.25 (0.07-0.88)	0.038	0.695
Non-Hispanic White	80/1477	0.40 (0.15-1.06)	0.071	
Other	24/463	0.24 (0.09-0.66)	0.008	
<b>Education levels</b>				
<12	158/1645	0.55 (0.27-1.11)	0.101	
12	70/1135	0.31 (0.11-0.93)	0.041	0.093
>12	19/530	0.11 (0.03-0.50)	0.006	

**Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

\* Analyses were adjusted for age, sex, race/ethnicity and education level.

† Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.

### Association between number of ICVHMs and sarcopenia

32% of participants with sarcopenia had only 1 ICVHM and 3% had 5 ideal ICVHMs. In participants without sarcopenia, up to 59% had  $\geq 3$  ICVHMs (**Figure 2**). Logistic regression of the ICVHM number and the risk of sarcopenia revealed that the higher the number of ICVHMs, the lower the risk of sarcopenia. When participants had 3 ideal CVH metrics, the risk of sarcopenia decreased by 50% compared to participants with non-ideal CVH metrics (aOR: 0.47, 95% CI: 0.27-0.81,  $P = 0.010$ ). If the number of ICVHMs was  $\geq 5$ , the risk of sarcopenia decreased by up to

85% (aOR: 0.15, 95% CI: 0.06-0.38,  $P < 0.001$ ; **Figure 3**).

**Association between different individual CVH components and sarcopenia**

In the subgroup analysis of the seven individual CVH components, participants defined as intermediate or poor CVH had a higher risk of sarcopenia risk than those with ideal CVH in all CVH metric subgroups except for the subgroup with cigarette smoking status. Especially in the BMI and healthy diet score subgroups, the risk of sarcopenia decreased > 90% (BMI: [aOR: 0.07, 95% CI: 0.03-0.15,  $P < 0.001$ ]; healthy diet score: [aOR: 0.05, 95% CI: 0.01-0.41,  $P = 0.007$ ]). Similar trends between increasing levels of CVH components for BMI, healthy diet scores, fasting plasma glucose levels, Physical activity, and blood pressure, and a decreasing risk of sarcopenia (all  $P$  for trend < 0.05; **Table 4**).

**Table 4. Adjusted prevalence ratios (95% CI) of Sarcopenia by individual component of CVH Metrics.**

Variable	OR *	95%CI	P value	P for trend
<b>Smoking status</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.75	0.30-1.88	0.538	0.832
Ideal	1.06	0.66-1.70	0.815	
<b>Body mass index</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.28	0.19-0.42	<0.001	<0.001
Ideal	0.07	0.03-0.15	<0.001	
<b>Healthy diet score</b>				

Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.69	0.45-1.06	0.010	0.043
Ideal	0.05	0.01-0.41	0.007	
<b>Total cholesterol</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	1.11	0.70-1.78	0.656	0.601
Ideal	0.91	0.58-1.43	0.671	
<b>Fasting plasma glucose</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	1.22	0.70-2.24	0.514	<0.001
Ideal	0.49	0.29-0.81	0.008	
<b>Physical activity</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.68	0.28-1.62	0.383	0.036
Ideal	0.68	0.48-0.97	0.037	
<b>Blood pressure</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.68	0.43-1.08	0.110	<0.001
Ideal	0.37	0.25-0.56	<0.001	

**Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

\* Analyses were adjusted for age, sex, race/ethnicity and education level.

## Discussion

This study used nationwide, population-based, cross-sectional data to demonstrate a significant association between CVH and sarcopenia and

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5 showed a significantly 60% decreased adjusted risk of sarcopenia in subjects with better CVH metrics. For each unit increase in the metrics of  
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7 CVH, the risk of CVDs decreased by 24%. Furthermore, higher intermediate or ideal CVH metrics were associated with a lower prevalence of  
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9 sarcopenia.  
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11 Our study yielded several interesting findings. First, the CVH metrics were not only associated with CVDs, but also non-CVDs, including  
12 sarcopenia. This result agreed with Han et al., [15] who also reported that sarcopenia was independently associated with cardiovascular risk  
13 factors, including diabetes and hypertension. And these risk factors were shown to be associated with the prevalence of sarcopenia defined by  
14 the recommended algorithm of the Asian Working Group in the Chinese elderly. [14] However, these results may only be applicable in patient  
15 with high-risk cardiovascular risk factors. In order to explore the association between sarcopenia and the common individual with average or  
16 only slightly unfavorable levels of risk factors, we chose CVH and elaborated on the detail and found that higher intermediate or ideal CVH  
17 metrics were associated with a lower prevalence of sarcopenia, as defined by the recommended algorithm of the FNIH in American adults. This  
18 finding suggests that the level of CVH influences the incidence of sarcopenia and emphasizes the greater importance of CVH for health care and  
19 medical conditions. A previous study showed that the presence of more desirable CVH indicators was associated with a significant reduction in  
20 CVD morbidity and mortality [16]. Our study broadens the application value of the CVH metrics; specifically, the higher the number of  
21 intermediate or ideal CVH metrics, the lower the incidence of sarcopenia. It showed that only a small percentage of American adults met the  
22 ideal criteria for 6 or 7 ideal health metrics. This result is disappointing, but perhaps not surprising. Furthermore, this result challenges clinical  
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5 and public health professionals to keep steering the health metrics in the desired direction. In the meantime, additional research is warranted in  
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7 the future to explore CVH and non-cardiovascular fields to increase public awareness of CVH and promote achievement of AHA 2030 goals.

8  
9 Second, we further observed the effects of CVH metrics on sarcopenia in different subgroups. We have reported that CVH influences the  
10  
11 incidence of sarcopenia not only in the elderly population, [14] but in the younger population. In addition, we demonstrated similar results in the  
12  
13 ethnicity subgroups. Surprisingly, it appeared that poor CVH metrics in females did not affect the prevalence of sarcopenia. However, we found  
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15 that the effect of CVH metrics was even stronger in young and middle-aged females than in males. Sex differences in antioxidant status may  
16  
17 have contributed to this phenomenon. Earlier studies demonstrated significant sex-dependent differences in GPx (selenoproteins, such as GPx-1  
18  
19 and GPx-3) activity, [17] while postmenopausal females have relatively high levels of systemic oxidative stress. [18] This finding suggests that  
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21 younger female may have higher levels of antioxidant enzymes and poor CVH metrics may significantly disrupt the antioxidant levels, and thus  
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23 make the individual more susceptible to sarcopenia.  
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28 Third, we attempted to determine the effect of each indicator in CVH alone on sarcopenia in this study. Our study showed that reduced  
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30 fasting plasma glucose levels were associated with a decreased risk of sarcopenia. This was consistent with the results of previous studies. [19]  
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32 This finding may be attributed to the fact that higher blood glucose levels accelerate the loss of muscle mass and strength. [20] In addition, ideal  
33  
34 blood pressure was the second significant feature associated with sarcopenia. Han P et al. [14] also found that hypertension is an independent  
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36 risk factor for sarcopenia. Although the mechanism underlying sarcopenia and hypertension is currently unknown, recent studies have concluded  
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5 that inflammatory factors during aging could impair blood flow by damaging the microvascular endothelium, [21] which exerted a detrimental  
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7 effect on the body of the elderly. Additional studies are needed to elucidate the causal relationship between hypertension and sarcopenia. Healthy  
8  
9 eating is significantly associated with sarcopenia. The Papaioannou study [22] highlighted the beneficial link between healthy eating and  
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11 sarcopenia risk. There are several possible mechanisms to explain the beneficial effects of a healthy diet on skeletal muscle. First, a healthy diet  
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13 rich in fruits and vegetables prevents metabolic acidosis and reduces protein hydrolysis and amino acid catabolism, thus reducing the risk of  
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15 sarcopenia. [23] In addition, unfavorable dietary patterns, including foods rich in saturated fats, may be detrimental to the maintenance of muscle  
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17 health, [24] while a fiber-rich diet reduces the risk of sarcopenia. [25] Some studies, however, suggest that a lower BMI indicates the presence of  
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19 sarcopenia and malnutrition and is associated with higher mortality in the older population. [26] Conversely, obese patients may have a survival  
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21 benefit. [27] However, our study still found that being overweight or obese can significantly increase the risk of sarcopenia. The poor prediction  
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23 of physical activity in the present study was unexpected, in contrast to previous studies [28] that suggested only ideal physical activity does  
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25 appear to be associated with the onset of sarcopenia. This finding might be due to the population in our study cohort included only young and  
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27 middle-aged adults. Physical activity may be crucial for the occurrence of sarcopenia in the elderly population.

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32 Our study has several limitations. First and foremost, cigarette smoking, physical activity, and diet were self-reported, and subjected to  
33  
34 misclassification and recall bias, which can lead to an over- or under-estimated association between CVH and sarcopenia. Moreover, as noted  
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36 above, for practical reasons, we were not fully compliant with all of the AHA 2020 health indicators. Finally, our study was cross-sectional, so  
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5 the association between CVH and sarcopenia cannot be interpreted as a direct cause-and-effect relationship.  
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## 8 9 **Conclusion**

10  
11 In conclusion, our findings suggested a relationship between CVH indicators and the prevalence of sarcopenia among US adults. Our analysis  
12 confirms that CVH extends beyond protection against cardiovascular disease. More research is needed to clarify the association between CVH  
13 and other non-CVDs. The results of our study can help facilitate the 2030 goal of achieving CVH for all because the AHA 2030 goal may be  
14 supported by efforts to reduce the prevalence of sarcopenia.  
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## 23 **Contributorship statement**

24  
25 The authors' contributions were as follows; WHC: participated in formulating the research question, design of analyses, interpretation of the  
26 data, drafting the manuscript, revising the manuscript, and the approval of the final version; SSS: participated in the design of analyses, data  
27 analysis, revising the manuscript, and approval of the final version; YZJ: drafting the manuscript, revising the manuscript, and the approval of  
28 the final version; YL: interpretation of the data and the approval of the final version; KHC: participated in formulating the research question,  
29 design of analyses, revising the manuscript, and the approval of the final version; RCH: participated in formulating the research question, design  
30 of analyses, data analysis, interpretation of the data, and the approval of the final version; KH: participated in formulating the research question,  
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5 design of analyses, data analysis, interpretation of the data, and the approval of the final version; and all authors: read and approved the final  
6  
7 version of the manuscript and are responsible for all aspects of the manuscript.  
8  
9

### 10 11 **Competing interests**

12  
13  
14 WHC, SSS, YZJ, YL, KHC, RCH and KH report no conflicts of interest.  
15  
16

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### 29 **Data sharing statement**

30  
31 None  
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37  
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5 **Figure Legend**

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7 **Title to Figure 1**

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9 Flowchart.

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11 **Title to Figure 2**

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13 Proportion of ICVHMs in sarcopenia and non-sarcopenia.

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16 **Title to Figure 3**

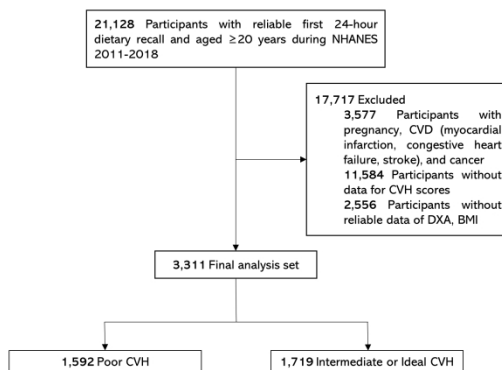
17  
18 Association between number of ICVHMs and sarcopenia

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21 **Legend to Figure 3**

22  
23 Abbreviation: ICVHMs, Ideal cardiovascular health metrics.

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25 Model: Adjusted by age, sex, race/ethnicity, education, and alcohol use.

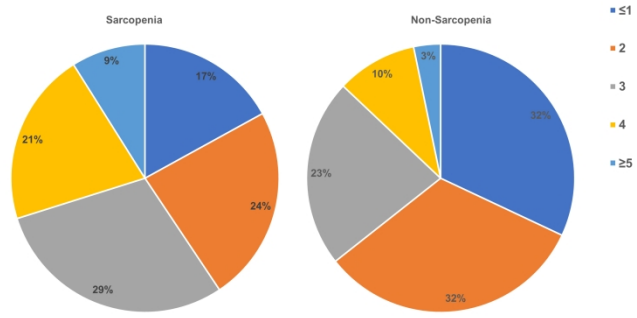
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Flowchart.

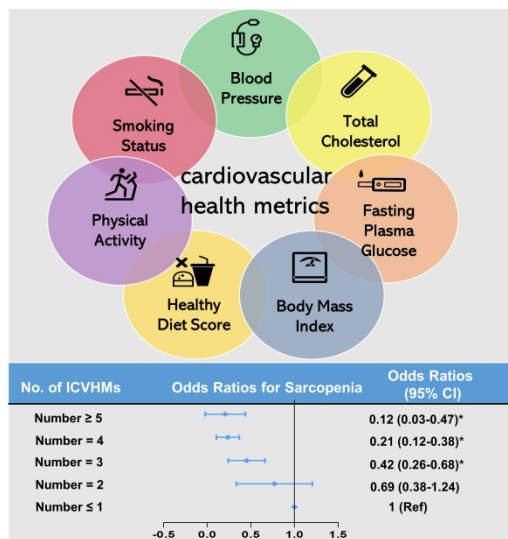
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Proportion of ICVHMs in sarcopenia and non-sarcopenia.

338x190mm (300 x 300 DPI)



Association between number of ICVHMs and sarcopenia

338x190mm (300 x 300 DPI)



**Tables S1 The association between CVH metrics and Sarcopenia by age subgroup in sex**

Characteristics	CVH levels, OR (95%CI) *		P value	P for interaction
	Poor CVH	Intermediate or Ideal CVH		
<b>Male</b>				
< 45	1[Ref]	0.46 (0.24-0.88)	0.022	0.725
45 - 59	1[Ref]	0.35 (0.12-1.06) <sup>9</sup>	0.069	
<b>Female</b>				
< 45	1[Ref]	0.14 (0.05-0.40)	< 0.001	0.173
45 - 59	1[Ref]	0.57 (0.10-3.29)	0.534	

**Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

\* Analyses were adjusted for race/ethnicity, education level and alcohol use.

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-11
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	6
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10-11
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11 Table 2
		(b) Indicate number of participants with missing data for each variable of interest	NA

Outcome data	15*	Report numbers of outcome events or summary measures	Table 3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12
		(b) Report category boundaries when continuous variables were categorized	9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-13
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Ideal cardiovascular health metrics: Are they just cardiovascular protective factors?

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Date Submitted by the Author:	09-Jun-2022
Complete List of Authors:	Chen, Weihua; Fujian Medical University Affiliated Longyan First Hospital, Shi, Shanshan; Longyan First Affiliated Hospital of Fujian Medical University; Fujian Medical University Jiang, Yizhou; State Key Laboratory of Cardiovascular Disease, Fuwai Hospital, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences and Peking Union Medical College Chen, Kaihong; Fujian Medical University Affiliated Longyan First Hospital, Department of Cardiology Liao, Ying; Longyan First Affiliated Hospital of Fujian Medical University Huang, Rongchong; Capital Medical University Huang, Kun; Tsinghua University, Department of Industrial Engineering
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Cardiovascular medicine
Keywords:	Cardiology < INTERNAL MEDICINE, Adult cardiology < CARDIOLOGY, Public health < INFECTIOUS DISEASES

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5 **1 Ideal cardiovascular health metrics: Are they just cardiovascular protective factors?**

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7 2 Weihua Chen<sup>1,2†</sup>, Shanshan Shi<sup>1,2†</sup>, Yizhou Jiang<sup>3†</sup>, Kaihong Chen<sup>1</sup>, Ying Liao<sup>1</sup>, Rongchong Huang<sup>4\*</sup>, Kun Huang<sup>5\*</sup>

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23 **Word count : 4287**

24 **Table number: 4**

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5 31 **Abstract**

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7 32 **Objective:** The American Heart Association (AHA) proposed the concept of ideal cardiovascular health (CVH) to reduce the risk of  
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9 33 cardiovascular mortality. We attempted to broaden the impact of CVH and further contribute to AHA 2030 goals by identifying the relationship  
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11 34 between CVH and non-cardiovascular diseases such as sarcopenia.

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14 35 **Design:** Cross-sectional survey

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16 36 **Setting:** National Health and Nutrition Examination Survey conducted in the USA from 2011 to 2018.

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18 37 **Participants:** This study included participants with reliable first 24-h dietary recall and  $\geq 20$  years of age and excluded those who could not  
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20 38 diagnose sarcopenia or insufficient data to calculate the CVH scores.

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22 39 **Primary and secondary outcome measures:** The prevalence of sarcopenia as measured by dual-energy X-ray absorptiometry.

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24 40 **Results:** This cohort study involving 3,311 adults > 20 years comprised 1,329 females (42.41%). The number of intermediate or ideal and poor  
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26 41 CVH participants was 1,719 and 1,592 with mean CVH score of  $9.32 \pm 0.06$  and  $5.43 \pm 0.05$ , respectively. After adjusting for related  
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28 42 confounding factors, intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (adjusted odds ratio [aOR]:  
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30 43 0.39, 95% CI: 0.22-0.69,  $P < 0.001$ ) and the odds of sarcopenia was significantly lower for each incremental increase of 1 in CVH metrics (aOR:  
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32 44 0.76, 95% CI: 0.70-0.83,  $P < 0.001$ ). Moreover, if the number of ideal CVH metrics was > 5, the odds of sarcopenia decreased by up to 85%  
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35 45 (aOR: 0.15, 95% CI: 0.06-0.38,  $P < 0.001$ ).  
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5 46 **Conclusions:** Our findings suggest a relationship between the CVH and the prevalence of sarcopenia in adults. The results of our study can  
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7 47 contribute to achieving the 2030 public health goal of achieving CVH for all, which may be supported by efforts to reduce the prevalence of  
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9 48 sarcopenia.

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11 49 **Keywords:** cardiovascular health metrics, sarcopenia, NHANES  
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#### 15 16 51 **Strengths and limitations of this study**

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18 52 This study benefited from the large, nationally representative data set and rigorous research methods of the National Health and Nutrition  
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21 53 Examination Survey.

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23 54 This study suggests a relationship between the CVH and the prevalence of non-cardiovascular disease, sarcopenia. The results of our study  
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25 55 can help facilitate the 2030 goal of achieving CVH for all because the AHA 2030 goal may be supported by efforts to reduce the prevalence of  
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28 56 sarcopenia.

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30 57 The limitations of this study were that data were derived from cross-sectional studies and that the relationship was not necessarily identified  
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32 58 as causal.

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35 59 Use of self-reported data might result in recall bias.  
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## 61 Introduction

62 Life expectancy in the United States has been stagnant since 2010 which has been attributed to a lack of progress in cardiovascular disease  
63 mortality. (1) Indeed, cardiovascular disease (CVD) remains the primary cause of mortality globally and a huge burden on public health  
64 expenditure. (2) Previous investigators have used the Framingham and SCORE risk estimation systems to assess a patient's risk for CVD. (3,4)  
65 These risk scores are primarily derived from the development and establishment of effective primary and secondary prevention interventions for  
66 high-risk populations. However, individuals with significantly elevated levels of risk factors are relatively uncommon in the population. Most  
67 CVD and stroke events occur in individuals with average or only slightly unfavorable levels of risk factors. Therefore, the concept of  
68 cardiovascular health (CVH) was introduced to reduce the risk of cardiovascular mortality in 2010. (5) CVH includes seven metrics, including  
69 body mass index (BMI), cigarette smoking, physical activity, dietary intake, total cholesterol level, blood pressure, and fasting glucose level. (5)  
70 The beneficial effects of ideal CVH metrics are widely supported by mounts of scientific research. (6) However, a recent study showed that the  
71 prevalence of ideal CVH status is low on some metrics, such as dietary pattern. (7) Moreover, a study involving the offspring of Framingham  
72 participants showed that the decreasing presence of ideal CVH metrics over the past 20 years has resulted in increasing risks of subclinical  
73 diseases, CVDs, and death. (8) Therefore, there is a long way to go regarding the "Strategic Impact Goals for 2030 and Beyond" issued by the  
74 American Heart Association (AHA).

75 Previous studies have suggested that an ideal CVH is negatively associated with age-related diseases. (9) Sarcopenia, marked by the age-

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5 76 related loss of muscle mass, strength, and function, has become a severe medical problem in the current aging society. A meta-analysis indicated  
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7 77 that patients with sarcopenia have decreased function, and higher rates of falls and hospitalization. (10) Sarcopenia shares many common  
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9 78 pathogenic mechanisms with CVDs, such as hormonal changes, inflammation and oxidative stress. (11) Studies have confirmed that sarcopenia  
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11 79 is significantly associated with increased cardiovascular events or mortality, (12) and patients with CVDs are also more likely to develop  
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13 80 sarcopenia than age-matched controls. (13)

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16 81 Although several studies have explored the relationship between cardiovascular risk factors and sarcopenia, (14) it remains unclear whether  
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18 82 ideal CVH metrics are beneficial in sarcopenic populations.

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21 83 This study aimed to determine the relationship between CVH and sarcopenia by using the 2011-2018 National Health and Nutrition  
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23 84 Examination Survey (NHANES) data to contribute to the accomplishment of the AHA 2030 goals.

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## 27 28 29 86 **Methods**

### 30 31 87 **Patient and public involvement**

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33 88 NHANES is a nationally representative health survey designed and administered by the National Center for Health Statistics (NCHS) at the  
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35 89 Centers for Disease Control and Prevention (CDC). The NHANES was designed to represent the civilian non-institutionalized United States  
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37 90 population using a complex multistage probability sampling methodology. We conducted a retrospective analysis of a cohort of US population

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5 91 of the NHANES from 2011 to 2018. The NHANES includes extensive demographic data, physical examinations, laboratory tests, health-related  
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7 92 questionnaires and lists of prescription medications, which were measured at the start of the study. Further details on the data collection  
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9 93 procedure and analytical guidelines are publicly available on the NHANES website. (15) As shown in **Figure 1**, this study included participants  
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11 94 with reliable first 24-h dietary recall and  $\geq 20$  years of age during NHANES 2011-2018 (n = 21128). Of these participants, 17817 were excluded  
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13 95 based on the following: (i) CVD (myocardial infarction, congestive heart failure, and stroke) and cancer; (ii) insufficient data to calculate the  
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15 96 CVH scores; and (iii) no reliable dual-energy X-ray absorptiometry (DXA) and body mass index (BMI) data. Thus, 3311 participants were  
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17 97 enrolled in the present study.  
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### 22 23 99 **DXA, appendicular skeletal muscle mass, and the definition of sarcopenia**

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25 100 DXA whole-body scans were performed on participants 8-59 years of age using Hologic Discovery model A densitometers (Hologic, Inc.,  
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27 101 Bedford, MA, USA). DXA exclusion criteria included pregnancy, weight >300 pounds (136 kg, because of the weight limit of the scanner),  
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29 102 height > 6'5" (DXA table limitations), history of radiographic contrast material (barium) used in the past 7 days, or nuclear medicine studies in  
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31 103 the past 3 days. Hologic software (version 8.26: a3\*) was used to administer all scans.  
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35 104 Appendicular skeletal muscle mass was measured using DXA. The sarcopenia index was calculated as follows: sarcopenia index = total  
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37 105 appendicular skeletal muscle mass (in kg)/BMI (kg/m<sup>2</sup>).  
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5 106 Sarcopenia was defined as the lowest for sex-specific sarcopenia index cut-off values (0.789 for men and 0.512 for women), based on the  
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7 107 National Institutes of Health (FNIH).  
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11 109 **CVH metrics**

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14 110 CVH metrics include four health behaviors (cigarette smoking, physical activity, healthy dietary scores, and BMI) and three health factors (total  
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16 111 cholesterol level, blood pressure, and fasting plasma glucose level). (5) The definitions of ideal, intermediate, and poor CVH metrics for adults  
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18 112 are presented in **Table 1**. We used the Healthy Eating Index 2010 (HEI-2010) scores as a proxy of healthy dietary scores, which were calculated  
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20 113 using first-day 24-h dietary recall. HEI-2010 scores were based on a 12-component index, with total scores ranging from 0-100, and a higher  
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22 114 score indicating a healthier diet: total fruit; whole fruit; total vegetables; grains and beans; whole grains; dairy; total protein foods; seafood and  
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24 115 plant protein; fatty acids; refined grains; sodium; and empty calories. Participants with an HEI-2010 score  $\leq 50$  were assigned to poor health,  
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26 116 those with a score of 51-80 to intermediate health, and those with a score  $\geq 81$  to ideal health.  
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33 118 **Table 1. Distribution of ideal, intermediate and poor CVH<sup>†</sup> for each metric for adults free of CVD, NHANES 2011-2018**

AHA definitions of CVH for each metric	Total sample (n=3311)
<b>Smoking status, n (%)</b>	
Ideal            Never or quit > 12 months ago	1212 (40.1)

Intermediate	Former ≤ 12 months	202 (7.2)
Poor	Current smoking	1897 (52.8)
<b>Body mass index, n (%)</b>		
Ideal	< 25 kg/m <sup>2</sup>	1025 (30.3)
Intermediate	25-29.9 kg/m <sup>2</sup>	1080 (33.8)
Poor	≥ 30 kg/m <sup>2</sup>	1206 (35.8)
<b>Physical activity, n (%)</b>		
Ideal	≥ 150 min/week moderate or ≥ 75 min/week vigorous or ≥ 150 min/week moderate + vigorous	1553 (48.1)
Intermediate	1-149 min/week moderate or 1-74 min /week vigorous or 1-149 min/week moderate + vigorous	218 (7.4)
Poor	None	1540 (44.5)
<b>Healthy diet score *, n (%)</b>		
Ideal	4-5 components	42 (1.7)
Intermediate	2-3 components	1199 (37.9)
Poor	0-1 components	2070 (60.4)
<b>Total cholesterol, n (%)</b>		
Ideal	< 200 mg/dL	1751 (49.8)
Intermediate	200-239 mg/dL or treated to goal	925 (30.3)
Poor	≥ 240 mg/dL	635 (20.0)
<b>Blood pressure, n (%)</b>		
Ideal	SBP < 120 or DBP < 80 mmHg	1459 (45.2)
Intermediate	SBP 120-139 or DBP 80-89 mmHg or treated to goal	1180 (33.6)
Poor	SBP ≥ 140 or DBP ≥ 90 mmHg	744 (21.2)
<b>Fasting plasma glucose, n (%)</b>		
Ideal	< 100 mg/dL	2282 (75.8)
Intermediate	100-125 mg/dL or treated to goal	713 (16.7)
Poor	≥ 126 mg/dL	316 (7.6)

119 **Abbreviation:** CVH, cardiovascular health; CVD, cardiovascular disease; NHANES, National Health and Nutrition Examination

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5 120 Survey; AHA, The American Heart Association; DBP, diastolic blood pressure; SBP, systolic blood pressure.

6 121 † CVH is defined from AHA in 2010. (5)

7 122 \* AHA's healthy diet score includes five components: fruits and vegetables, whole grain, fish, sodium, and sugar-sweeten  
8 123 beverage, and a very small proportion (<0.5%) of U.S. adults meet the ideal healthy diet. HEI-2010 is a continuous score consisting  
9 124 of 12 components representing major food groups including fruit and vegetables, whole grains, proteins, dairy, oils, sodium, and  
10 125 empty calories. HEI-2010 score ranges from 0 to 100 with a higher score indicates more healthy diet. HEI-2010 has been validated  
11 126 to represent the diet quality in population. We used HEI-2010 as a proxy for AHA's healthy diet score with ideal diet: HEI-2010  $\geq$  81;  
12 127 intermediate diet: 51-80; and poor diet:  $\leq$  50.  
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14 129 Although the AHA relies on fasting glucose to determine hyperglycemia, we use hemoglobin A1c (HbA1c) concentrations for two reasons.  
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16 130 First, recent recommendations from the American Diabetes Association allow the use of HbA1c to diagnose diabetes. Second, a significant  
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18 131 percentage of NHANES participants who took the test did not fast. Therefore, we used HbA1c values < 5.7%, 5.7%-6.4%, and  $\geq$  6.5% as a  
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20 132 proxy for fasting plasma glucose levels < 100 mg/dL, 100 to < 126 mg/dL, and  $\geq$  126 mg/dL. Participants who reported having diabetes or  
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22 133 being treated with insulin or an oral medication to lower blood glucose and had an HbA1c concentration between 5.7% and 6.4% were  
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24 134 categorized as intermediate health. Similarly, participants who reported taking cholesterol-lowering or antihypertensive medications and were  
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26 135 treated to goal were categorized as “intermediate,” whereas participants with these conditions who were untreated or who were not treated to  
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28 136 goal were categorized as “poor” for that health factor. Use of antihypertensive, cholesterol-lowering, and glucose-lowering medications were  
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30 137 self-reported. Total cholesterol and plasma glucose levels were measured with enzymatic methods  
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32 138 (<https://www.cdc.gov/nchs/nhanes/index.htm>). BMI was calculated as the weight in kilograms divided by the height in meters squared. The  
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5 139 mean blood pressure was estimated from up to three readings obtained under standard conditions during a single physical examination.  
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7 140 For each metric, participants received 0, 1, or 2 points, representing poor, intermediate, or ideal categories, respectively. Participants with  
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9 141 overall scores of 0-7, 8-11, or 12-14 points were categorized as having poor, intermediate, or ideal CVH, respectively. Owing to the relatively  
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11 142 low number of people with an ideal CVH score in this sample, the intermediate and ideal CVH categories were combined.  
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#### 16 144 **Statistical analysis**

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18 145 We used the NHANES recommended weights to account for planned oversampling of specific groups. The continuous variables were expressed  
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20 146 as the mean  $\pm$  standard error, and the categorical variables were presented as counts (percentages). Baseline characteristics between the two  
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22 147 CVH groups were compared using a t-test for continuous variables and a  $\chi^2$  test for categorical variables.  
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25 148 Multiple logistic regression was used to examine the independent influence of CVH on sarcopenia comparing poor CVH versus intermediate  
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27 149 or ideal CVH after adjustments for potential confounders, such as age, sex, and race/ethnicity, educational level and alcohol. The odds ratio (OR)  
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29 150 and 95% confidence interval (CI) were computed. We explored the relationship between CVH and sarcopenia in different subgroups (age, sex,  
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31 151 race/ethnicity, education level and alcohol use). We also separately estimated the association between individual components of the CVH  
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33 152 metrics and sarcopenia. When assessing the role of individual components, the age, sex, race/ethnicity, and education level were adjusted.  
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35 153 Furthermore, we used multiple logistic regression analysis to assess the effect of a different number of ideal cardiovascular health metrics  
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5 154 (ICVHMs) on the incidence of sarcopenia. A two-sided  $P$ -value  $< 0.05$  indicated significance for all analyses. All data analyses were performed  
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7 155 using SAS Release 9.4 (SAS Institute) and Survey package in R software (version 4.0.4; R Foundation for Statistical Computing, Vienna,  
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9 156 Austria).

## 15 158 **Results**

### 17 159 **Baseline characteristics**

20 160 This study shown that only 1.7% of the participants met the ideal diet criteria. The frequency in the present sample of participants meeting the  
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22 161 ideal level for the remainder of CVH metrics were cigarette smoking (weighted proportion, 40.1%), diabetes (weighted, 75.8%), total cholesterol  
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24 162 level (weighted, 49.8%), blood pressure (weighted, 45.2%), physical activity (weighted, 44.5%), and BMI (weighted, 30.3%) (**Table 1**).

26 163 This cohort study involved 3311 adults  $\geq 20$  years of age, comprising 1329 females (weighte, 42.4%) and 1982 males (weighted, 47.6%),  
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29 164 with a weighted mean (SE) age of  $40.0 \pm 0.4$  years. 1477 (weighted, 66.6%) were of non-Hispanic white ancestry, 753 (weighted, 15.7%) of  
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31 165 Hispanic ancestry, and 618 (weighted, 9.6%) of non-Hispanic Black ancestry. The study population characteristics are listed in **Table 2** by CVH  
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33 166 metrics. The number of intermediate or ideal and CVH participants was 1719 and 1592, with mean CVH metrics of  $9.3 \pm 0.1$  and  $5.4 \pm 0.1$ ,  
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35 167 respectively. The differences of CVH metrics were significant for age, race/ethnicity, and education ( $P < 0.001$ ). The frequency in the present  
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37 168 sample of sarcopenia in participants with poor CVH metrics was 9.9%, more than two times as participants with intermediate or ideal CVH  
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169 metrics (3.6%). Moreover, we analyzed the characteristics of this study population by sarcopenic status. Sarcopenia was identified in 32.1% of  
 170 89 females based on the sarcopenia criteria and the Hispanic more like to develop sarcopenia (36.5%) compared with other races/ethnicities.  
 171 Heavy use of alcohol did not show significant differences between both groups ( $P = 0.821$ ). Furthermore, the patient with sarcopenia had poor  
 172 education level, BMI risk, healthy diet score risk, blood pressure risk, fasting plasma glucose risk, and overall CVH metrics. And more detailed  
 173 analyses are presented in **Table S1**.

175 **Table 2. Baseline characteristics of the study population**

Characteristics	Total (n=3311)	Intermediate or Ideal CVH (n=1719)	Poor CVH (n=1592)	<i>P</i> value
<b>Age, mean (SE), years</b>	40.0 (0.4)	37.3 (0.5)	42.9 (0.4)	< 0.001
<b>Female, n (%)</b>	1329 (42.4)	614 (41.5)	715 (43.5)	0.382
<b>Race/ethnicity, n (%)</b>				
Hispanic	753 (15.7)	362 (15.3)	391 (16.0)	
Non-Hispanic Black	618 (9.6)	232 (7.2)	386 (12.4)	
Non-Hispanic White	1477 (66.6)	760 (69.8)	717 (63.0)	< 0.001
Other	463 (8.1)	238 (7.7)	225 (8.6)	
<b>Heavy use of alcohol, n (%) *</b>				
< 12	2558 (96.4)	1273 (97.4)	1285 (95.1)	
≥ 12	103 (3.6)	40 (2.6)	63 (4.9)	0.062
<b>Education levels, n (%)</b>				
< 12	1645 (44.9)	735 (41.8)	910 (48.3)	
12	1135 (35.7)	543 (35.5)	592 (36.0)	0.005

> 12	530(19.4)	313 (22.7)	217 (15.8)	
<b>Scores of CVH metrics, mean (SE)</b>	7.49 (0.1)	9.32 (0.1)	5.43 (0.1)	< 0.001
<b>Sarcopenia, n (%)</b>				
Yes	247 (6.6)	67 (3.6)	180 (9.9)	
No	3064 (94.4)	1525 (96.4)	1539 (90.1)	< 0.001

**Abbreviation:** CVH, cardiovascular health.

\* Data missing > 5%

### Association between CVH metrics and sarcopenia

The intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (odds ratio [aOR]: 0.34 0.21-0.54,  $P < 0.001$ ; **Table 3**). After adjusting for age, sex, race/ethnicity, education level, and alcohol use, intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (adjusted odds ratio [aOR]: 0.39, 95% CI: 0.22-0.69,  $P < 0.001$ ). In the fully adjusted model, the odds of sarcopenia was significantly lower for each incremental increase of 1 in CVH metrics (aOR: 0.76, 95% CI: 0.70-0.83,  $P < 0.001$ ). Further stratified and interaction analyses were performed for age, sex, race/ethnicity, and education level. Notably, the age group showed stronger association in the subgroup aged < 45 years (aOR: 0.35, 95% CI: 0.20-0.64,  $P < 0.001$ ). And the association between intermediate or ideal CVH and sarcopenia was not significant in female and lower education level subgroups. Further, the effect of different ages was explored in the female subgroup. In the female participants < 45 years of age, intermediate or ideal CVH scores remained an independent protective factor for sarcopenia (aOR: 0.14, 95% CI: 0.05-0.40,  $P < 0.001$ ; **Table S2**). Among subgroups of non-Hispanic Black and other ancestry, the odds of

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5 190 sarcopenia decreased by 75% in participants with intermediate or ideal CVH than in participants with poor CVH (aOR: 0.25, 95% CI: 0.07-0.88,  
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7 191  $P = 0.038$ ; aOR: 0.24, 95%CI: 0.09-0.66,  $P = 0.008$ ; Table 3). For all of subgroups, there was no significant interaction (all  $P$  for interaction  $>$   
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15 **Table 3. The association between CVH metrics and Sarcopenia by selected subgroups**

Variable	No. (%)	Intermediate or Ideal CVH OR (95%CI) †	<i>P</i> value	Intermediate or Ideal CVH OR (95%CI) *	<i>P</i> value	<i>P</i> for interaction
<b>Continuous</b>						
CVH (per 1 score)	247/3311	0.75 (0.70-0.81)	<0.001	0.76 (0.70-0.83)	<0.001	-
<b>Categories †</b>						
Poor CVH	180/1719	1[Ref]	-	1[Ref]	-	-
Intermediate or Ideal CVH	67/1592	0.34 (0.21-0.54)	<0.001	0.39 (0.22-0.69)	<0.001	-
<b>Subgroup</b>						
<b>Age</b>						
<45	112/2024	0.40 (0.24-0.67)	<0.001	0.35 (0.20-0.64)	<0.001	0.858

45-59	135/1287	0.33 (0.15-0.75)	0.009	0.40 (0.16-1.04)	0.067	
<b>Sex</b>						
Male	158/1982	0.37 (0.22-0.63)	<0.001	0.43 (0.23-0.82)	0.014	0.539
Female	89/1329	0.26 (0.08-0.84)	0.025	0.30 (0.07-1.32)	0.117	
<b>Race</b>						
Hispanic	126/753	0.38 (0.23-0.63)	<0.001	0.42 (0.23-0.77)	0.007	
Non-Hispanic Black	17/618	0.16 (0.04-0.73)	0.019	0.25 (0.07-0.88)	0.038	0.695
Non-Hispanic White	80/1477	0.30 (0.14-0.67)	0.004	0.40 (0.15-1.06)	0.071	
Other	24/463	0.35 (0.12-0.99)	0.047	0.24 (0.09-0.66)	0.008	
<b>Education levels</b>						
<12	158/1645	0.51 (0.28-0.91)	0.024	0.55 (0.27-1.11)	0.101	
12	70/1135	0.35 (0.14-0.88)	0.026	0.31 (0.11-0.93)	0.041	0.093
>12	19/530	0.24 (0.06-0.94)	0.040	0.11 (0.03-0.50)	0.006	

195 **Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

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5 196 † Unadjusted model.

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7 197 \* Analyses were adjusted for age, sex, race/ethnicity and education level.

8 198 Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.

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### 10 11 200 **Association between number of ICVHMs and sarcopenia**

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14 201 32% of participants with sarcopenia had only 1 ICVHM and 3% had 5 ideal ICVHMs. In participants without sarcopenia, up to 59% had  $\geq 3$   
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16 202 ICVHMs (**Figure 2**). Logistic regression of the ICVHM number and the odds of sarcopenia revealed that the higher the number of ICVHMs, the  
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18 203 lower the odds of sarcopenia. When participants had 3 ideal CVH metrics, the odds of sarcopenia decreased by 50% compared to participants  
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20 204 with non-ideal CVH metrics (aOR: 0.47, 95% CI: 0.27-0.81,  $P = 0.010$ ). If the number of ICVHMs was  $\geq 5$ , the odds of sarcopenia decreased by  
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22 205 up to 85% (aOR: 0.15, 95% CI: 0.06-0.38,  $P < 0.001$ ; **Figure 3**).

### 23 24 25 26 206 **Association between different individual CVH components and sarcopenia**

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29 207 In the subgroup analysis of the seven individual CVH components, participants defined as intermediate or poor CVH had a higher odds of  
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31 208 sarcopenia odds than those with ideal CVH in all CVH metric subgroups except for the subgroup with cigarette smoking status. Especially in the  
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33 209 BMI and healthy diet score subgroups, the odds of sarcopenia decreased  $> 90\%$  (BMI: [aOR: 0.07, 95% CI: 0.03-0.15,  $P < 0.001$ ]; healthy diet  
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35 210 score: [aOR: 0.05, 95% CI: 0.01-0.41,  $P = 0.007$ ]). Similar trends were observed between increasing levels of CVH components for BMI,  
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37 211 healthy diet scores, fasting plasma glucose levels, physical activity, and blood pressure, and a decreasing odds of sarcopenia (all  $P$  for trend  $<$

212 0.05; Table 4).

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214 **Table 4. Adjusted odds ratios (95% CI) of Sarcopenia by individual component of CVH Metrics.**

Variable	OR *	95%CI	P value	P for trend
<b>Smoking status</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.75	0.30-1.88	0.538	0.832
Ideal	1.06	0.66-1.70	0.815	
<b>Body mass index</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.28	0.19-0.42	<0.001	<0.001
Ideal	0.07	0.03-0.15	<0.001	
<b>Healthy diet score</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.69	0.45-1.06	0.010	0.043
Ideal	0.05	0.01-0.41	0.007	
<b>Total cholesterol</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	1.11	0.70-1.78	0.656	0.601
Ideal	0.91	0.58-1.43	0.671	
<b>Fasting plasma glucose</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	1.22	0.70-2.24	0.514	<0.001
Ideal	0.49	0.29-0.81	0.008	

**Physical activity**

Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.68	0.28-1.62	0.383	0.036
Ideal	0.68	0.48-0.97	0.037	

**Blood pressure**

Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.68	0.43-1.08	0.110	<0.001
Ideal	0.37	0.25-0.56	<0.001	

215 **Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

216 \* Analyses were adjusted for age, sex, race/ethnicity and education level.

217

**Discussion**

219 This study used nationwide, population-based, cross-sectional data to demonstrate a significant association between CVH and sarcopenia and  
 220 showed a significantly 60% decreased adjusted risk of sarcopenia in subjects with better CVH metrics. For each unit increase in the metrics of  
 221 CVH, the risk of CVDs decreased by 24%. Furthermore, higher intermediate or ideal CVH metrics were associated with a lower prevalence of  
 222 sarcopenia.

223 Our study yielded several interesting findings. First, the CVH metrics were not only associated with CVDs, but also non-CVDs, including  
 224 sarcopenia. This result agreed with Han et al., (16) who also reported that sarcopenia was independently associated with cardiovascular risk  
 225 factors, including diabetes and hypertension. And these risk factors were shown to be associated with the prevalence of sarcopenia defined by



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5 226 the recommended algorithm of the Asian Working Group in the Chinese elderly. (14) However, these results may only be applicable in patient  
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7 227 with high-risk cardiovascular risk factors. In order to explore the association between sarcopenia and the common individual with average or  
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9 228 only slightly unfavorable levels of risk factors, we chose CVH and elaborated on the detail and found that higher intermediate or ideal CVH  
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11 229 metrics were associated with a lower prevalence of sarcopenia, as defined by the recommended algorithm of the FNIH in American adults. This  
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13 230 finding suggests that the level of CVH influences the incidence of sarcopenia and emphasizes the greater importance of CVH for health care and  
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15 231 medical conditions. A previous study showed that the presence of more desirable CVH indicators was associated with a significant reduction in  
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17 232 CVD morbidity and mortality (17). Our study broadens the application value of the CVH metrics; specifically, the higher the number of  
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19 233 intermediate or ideal CVH metrics, the lower the incidence of sarcopenia. It showed that only a small percentage of American adults met the  
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21 234 ideal criteria for 6 or 7 ideal health metrics. This result is disappointing, but perhaps not surprising. Furthermore, this result challenges clinical  
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23 235 and public health professionals to keep steering the health metrics in the desired direction. In the meantime, additional research is warranted in  
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25 236 the future to explore CVH and non-cardiovascular fields to increase public awareness of CVH and promote achievement of AHA 2030 goals.

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28 237 Second, we further observed the effects of CVH metrics on sarcopenia in different subgroups. We have reported that CVH influences the  
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30 238 incidence of sarcopenia not only in the elderly population, (14) but in the younger population. In addition, we demonstrated similar results in the  
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32 239 ethnicity subgroups. Surprisingly, it appeared that poor CVH metrics in females did not affect the prevalence of sarcopenia. However, we found  
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34 240 that the effect of CVH metrics was even stronger in young and middle-aged females than in males. Sex differences in antioxidant status may  
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5 241 have contributed to this phenomenon. Earlier studies demonstrated significant sex-dependent differences in GPx (selenoproteins, such as GPx-1  
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7 242 and GPx-3) activity, (18) while postmenopausal females have relatively high levels of systemic oxidative stress. (19) This finding suggests that  
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9 243 younger female may have higher levels of antioxidant enzymes and poor CVH metrics may significantly disrupt the antioxidant levels, and thus  
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11 244 make the individual more susceptible to sarcopenia.

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14 245 Third, we attempted to determine the effect of each indicator in CVH alone on sarcopenia in this study. Our study showed that reduced  
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16 246 fasting plasma glucose levels were associated with a decreased risk of sarcopenia. This was consistent with the results of previous studies. (20)  
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18 247 This finding may be attributed to the fact that higher blood glucose levels accelerate the loss of muscle mass and strength. (21) In addition, ideal  
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20 248 blood pressure was the second significant feature associated with sarcopenia. Han P et al. (14) also found that hypertension is an independent  
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22 249 risk factor for sarcopenia. Although the mechanism underlying sarcopenia and hypertension is currently unknown, recent studies have concluded  
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24 250 that inflammatory factors during aging could impair blood flow by damaging the microvascular endothelium, (22) which exerted a detrimental  
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26 251 effect on the body of the elderly. Additional studies are needed to elucidate the causal relationship between hypertension and sarcopenia. Healthy  
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28 252 eating is significantly associated with sarcopenia. The Papaioannou study (23) highlighted the beneficial link between healthy eating and  
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30 253 sarcopenia risk. There are several possible mechanisms to explain the beneficial effects of a healthy diet on skeletal muscle. First, a healthy diet  
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32 254 rich in fruits and vegetables prevents metabolic acidosis and reduces protein hydrolysis and amino acid catabolism, thus reducing the risk of  
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34 255 sarcopenia. (24) In addition, unfavorable dietary patterns, including foods rich in saturated fats, may be detrimental to the maintenance of muscle  
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5 256 health, (25) while a fiber-rich diet reduces the risk of sarcopenia. (26) Some studies, however, suggest that a lower BMI indicates the presence of  
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7 257 sarcopenia and malnutrition and is associated with higher mortality in the older population. (27) Conversely, obese patients may have a survival  
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9 258 benefit. (28) However, our study still found that being overweight or obese can significantly increase the risk of sarcopenia. The poor prediction  
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11 259 of physical activity in the present study was unexpected, in contrast to previous studies (29) that suggested only ideal physical activity does  
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13 260 appear to be associated with the onset of sarcopenia. This finding might be due to the population in our study cohort included only young and  
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15 261 middle-aged adults. Physical activity may be crucial for the occurrence of sarcopenia in the elderly population.

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18 262 Our study has several limitations. First and foremost, cigarette smoking, physical activity, and diet were self-reported, and subjected to  
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20 263 misclassification and recall bias, which can lead to an over- or under-estimated association between CVH and sarcopenia. Second, as noted  
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22 264 above, for practical reasons, we were not fully compliant with all of the AHA 2020 health indicators. Moreover, our study was cross-sectional,  
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24 265 so the association between CVH and sarcopenia cannot be interpreted as a direct cause-and-effect relationship. Finally, 84 percent of initial  
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26 266 cohort has been excluded in this study, which will increase the variance of the odds ratio estimates. This can be improved when the larger dataset  
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28 267 is available in the future.

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### 33 34 269 **Conclusion**

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37 270 In conclusion, our findings suggested a relationship between CVH indicators and the prevalence of sarcopenia among US adults. Our analysis  
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5 271 confirms that CVH extends beyond protection against cardiovascular disease. More research is needed to clarify the association between CVH  
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7 272 and other non-CVDs. The results of our study can help facilitate the 2030 goal of achieving CVH for all because the AHA 2030 goal may be  
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9 273 supported by efforts to reduce the prevalence of sarcopenia.  
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11 274

#### 14 275 **Contributorship statement**

16 276 The authors' contributions were as follows; WHC: participated in formulating the research question, design of analyses, interpretation of the  
17  
18 277 data, drafting the manuscript, revising the manuscript, and the approval of the final version; SSS: participated in the design of analyses, data  
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20 278 analysis, revising the manuscript, and approval of the final version; YZJ: drafting the manuscript, revising the manuscript, and the approval of  
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22 279 the final version; YL: interpretation of the data and the approval of the final version; KHC: participated in formulating the research question,  
23  
24 280 design of analyses, revising the manuscript, and the approval of the final version; RCH: participated in formulating the research question, design  
25  
26 281 of analyses, data analysis, interpretation of the data, and the approval of the final version; KH: participated in formulating the research question,  
27  
28 282 design of analyses, data analysis, interpretation of the data, and the approval of the final version; and all authors: read and approved the final  
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30 283 version of the manuscript and are responsible for all aspects of the manuscript.  
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34 284

#### 37 285 **Competing interests**

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5 286 WHC, SSS, YZJ, YL, KHC, RCH and KH report no conflicts of interest.  
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9 288 **Funding**

10  
11 289 This study was supported by grants from the Summit Talent Plan, Beijing Hospital Management Center (plan no: DFL20190101) (Beijing,  
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13  
14 290 China), and the Natural Science Foundation of Fujian Provincial Science and Technology Department (2018J01405).  
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20 292 **Data sharing statement**

21  
22 293 None  
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27 295 **Acknowledgements**

28  
29 296 Additional Contributions: The authors thank all the participants and staff of the NHANES for their valuable contributions.  
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5 **Figure Legend**

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11 **Title to Figure 2**

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13 Proportion of ICVHMs in sarcopenia and non-sarcopenia.

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16 **Title to Figure 3**

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18 Association between number of ICVHMs and sarcopenia.

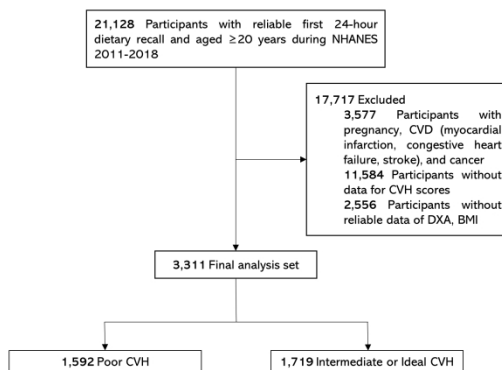
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21 **Legend to Figure 3**

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23 Abbreviation: ICVHMs, Ideal cardiovascular health metrics.

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25 Model: Adjusted by age, sex, race/ethnicity, education, and alcohol use.

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28 \*  $P < 0.05$ .

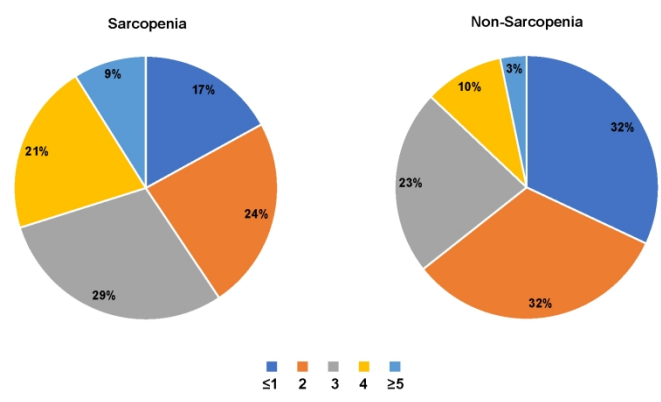
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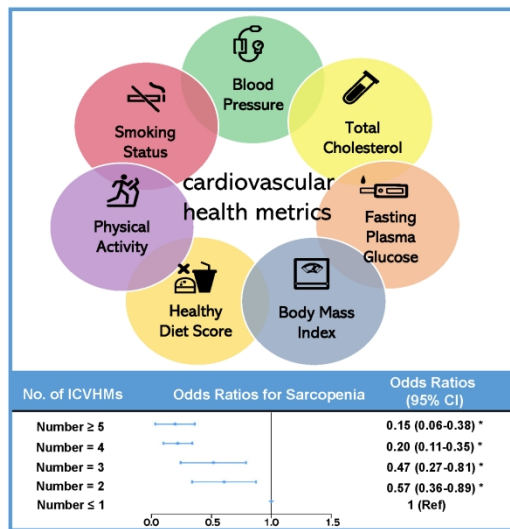
Flowchart.

338x190mm (300 x 300 DPI)

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Proportion of ICVHMs in sarcopenia and non-sarcopenia.  
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Association between number of ICVHMs and sarcopenia.

338x190mm (200 x 200 DPI)

**Table S1 Baseline characteristics of the study population by sarcopenic.**

<b>Characteristics</b>	<b>Non-sarcopenic (n=3064)</b>	<b>Sarcopenic (n=247)</b>	<b>p-value</b>
<b>Age, mean (SE), years</b>	39.7 (0.4)	43.8 (1.2)	0.002
<b>Female, n (%)</b>	1240 (43.1)	89 (32.1)	0.023
<b>Race/ethnicity, n (%)</b>			
Hispanic	627 (14.2)	126 (36.5)	
Non-Hispanic Black	601 (10.0)	17 (4.4)	< 0.001
Non-Hispanic White	1387(67.8)	80 (50.3)	
Other	439 (8.1)	24 (8.8)	
<b>Heavy use of alcohol, n (%)</b>			
<12	2389 (99.0)	169 (99.1)	0.821
≥12	92 (1.0)	11 (0.9)	
<b>Education level, n (%)</b>			
Less Than High School	1487 (43.9)	158 (57.6)	0.005
High School Diploma	1065 (35.8)	70 (34.7)	
More Than High School	511 (20.3)	19 (7.6)	
<b>Smoking risk, n (%)</b>			
Ideal	1094 (39.78)	118 (44.3)	0.507
Intermediate	190 (7.3)	12 (4.9)	
Poor	1780 (52.9)	117 (50.8)	
<b>Body mass index risk, n (%)</b>			
Ideal	1011 (32.2)	14 (4.4)	< 0.001
Intermediate	1022 (34.6)	58 (23.6)	
Poor	1031 (33.3)	175 (72.0)	
<b>Physical activity risk, n (%)</b>			

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5	Ideal	1435 (48.5)	105 (42.7)	
6	Intermediate	207 (7.5)	11 (5.5)	0.227
7	Poor	1422 (44.0)	131 (51.8)	
8				
9	<b>Healthy diet score risk, n (%)</b>			
10	Ideal	41 (1.8)	1 (0.0)	
11	Intermediate	1119 (38.3)	80 (31.0)	0.010
12	Poor	1904 (59.8)	166 (69.0)	
13				
14	<b>Total cholesterol risk, n (%)</b>			
15	Ideal	1651 (50.5)	100 (39.6)	
16	Intermediate	845 (29.9)	80 (35.8)	0.096
17	Poor	568 (19.6)	67 (24.6)	
18				
19	<b>Blood pressure risk, n (%)</b>			
20	Ideal	1387 (46.6)	72 (25.7)	
21	Intermediate	1016 (33.3)	92 (37.6)	< 0.001
22	Poor	661 (20.1)	83 (36.8)	
23				
24	<b>Fasting plasma glucose risk,</b>			
25	<b>n (%)</b>			
26	Ideal	2167 (77.3)	115 (53.0)	
27	Intermediate	628 (15.6)	85 (32.4)	< 0.001
28	Poor	269 (7.1)	47 (14.6)	
29				
30	<b>Scores of seven healthy</b>			
31	<b>metrics, mean (SE)</b>	7.6 (0.1)	5.9 (0.2)	< 0.001
32				
33	<b>Overall CVH metrics, n (%)</b>			
34	Poor	1539 (45.5)	180 (71.2)	
35	Intermediate or Ideal	1525 (54.5)	67 (28.8)	< 0.001
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**Abbreviations:** CVH, cardiovascular health.

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Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.

For peer review only

**Tables S2 The association between CVH metrics and Sarcopenia by age subgroup in sex**

Characteristics	CVH levels, OR (95%CI) *		P value	P for interaction
	Poor CVH	Intermediate or Ideal CVH		
<b>Male</b>				
< 45	1[Ref]	0.46 (0.24-0.88)	0.022	0.725
45 - 59	1[Ref]	0.35 (0.12-1.06)	0.069	
<b>Female</b>				
< 45	1[Ref]	0.14 (0.05-0.40)	< 0.001	0.173
45 - 59	1[Ref]	0.57 (0.10-3.29)	0.534	

**Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

\* Analyses were adjusted for race/ethnicity, education level and alcohol use.



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60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10-11
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	6
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10-11
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11 Table 2
		(b) Indicate number of participants with missing data for each variable of interest	NA

Outcome data	15*	Report numbers of outcome events or summary measures	Table 3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12
		(b) Report category boundaries when continuous variables were categorized	9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-13
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Association of sarcopenia with ideal cardiovascular health metrics among US adults: a cross-sectional study of NHANES data from 2011 to 2018

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5 1 **Association of sarcopenia with ideal cardiovascular health metrics among US adults: a cross-sectional study of NHANES**  
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7 2 **data from 2011 to 2018.**  
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24 **Word count : 4,281**

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5 31 **Abstract**

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7 32 **Objective:** The American Heart Association (AHA) proposed the concept of ideal cardiovascular health (CVH) to reduce the risk of  
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9 33 cardiovascular mortality. We attempted to broaden the impact of CVH and further contribute to AHA 2030 goals by identifying the  
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11 34 relationship between CVH and non-cardiovascular diseases such as sarcopenia.

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14 35 **Design:** Cross-sectional survey

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16 36 **Setting:** National Health and Nutrition Examination Survey conducted in the USA from 2011 to 2018.

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18 37 **Participants:** This study included participants with reliable first 24-h dietary recall and  $\geq 20$  years of age and excluded those who  
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20 38 could not diagnose sarcopenia or insufficient data to calculate the CVH scores.

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22 39 **Primary and secondary outcome measures:** The prevalence of sarcopenia as measured by dual-energy X-ray absorptiometry.

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24 40 **Results:** This cohort study involving 9,326 adults  $\geq 20$  years comprised 4,733 females (50.0%). The number of intermediate or ideal  
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26 41 and poor CVH participants was 5,654 and 3,672 with mean CVH score of  $9.70 \pm 0.03$  and  $5.66 \pm 0.04$ , respectively. After adjusting  
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28 42 for related confounding factors, intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH  
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30 43 (adjusted odds ratio [aOR]: 0.36, 95% CI: 0.26-0.50,  $P < 0.001$ ) and the odds of sarcopenia was significantly lower for each  
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32 44 incremental increase of 1 in CVH metrics (aOR: 0.75, 95% CI: 0.71-0.79,  $P < 0.001$ ). Moreover, if the number of ideal CVH metrics  
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34 45 was  $> 5$ , the odds of sarcopenia decreased by up to 84% (aOR: 0.16, 95% CI: 0.08-0.30).

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5 46 **Conclusions:** Our findings suggest a relationship between the CVH and the prevalence of sarcopenia in adults. The results of our  
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7 47 study can contribute to achieving the 2030 public health goal of achieving CVH for all, which may be supported by efforts to reduce  
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9 48 the prevalence of sarcopenia.

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11 49 **Keywords:** cardiovascular health metrics, sarcopenia, NHANES  
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#### 15 16 51 **Strengths and limitations of this study**

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18 52 The main strength of this study is the large sample representative of the adult population of US.

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20 53 Use of a validated survey instrument and standardized data collection methods allows for comparison with other studies.

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22 54 The limitations of this study were that data were derived from cross-sectional studies and that the relationship was not necessarily  
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24 55 identified as causal.

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26 56 Use of self-reported data might result in recall bias.

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28 57 A half of initial cohort has been excluded in this study, which will increase the variance of the odds ratio estimates.  
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## 61 Introduction

62 Life expectancy in the United States has been stagnant since 2010 which has been attributed to a lack of progress in cardiovascular  
63 disease mortality. (1) Indeed, cardiovascular disease (CVD) remains the primary cause of mortality globally and a huge burden on  
64 public health expenditure. (2) Previous investigators have used the Framingham and SCORE risk estimation systems to assess a  
65 patient's risk for CVD. (3,4) These risk scores are primarily derived from the development and establishment of effective primary and  
66 secondary prevention interventions for high-risk populations. However, individuals with significantly elevated levels of risk factors are  
67 relatively uncommon in the population. Most CVD and stroke events occur in individuals with average or only slightly unfavorable  
68 levels of risk factors. Therefore, the concept of cardiovascular health (CVH) was introduced to reduce the risk of cardiovascular  
69 mortality in 2010. (5) CVH includes seven metrics, including body mass index (BMI), cigarette smoking, physical activity, dietary  
70 intake, total cholesterol level, blood pressure, and fasting glucose level. (5) The beneficial effects of ideal CVH metrics are widely  
71 supported by mounts of scientific research. (6) However, a recent study showed that the prevalence of ideal CVH status is low on  
72 some metrics, such as dietary pattern. (7) Moreover, a study involving the offspring of Framingham participants showed that the  
73 decreasing presence of ideal CVH metrics over the past 20 years has resulted in increasing risks of subclinical diseases, CVDs, and  
74 death. (8) Therefore, there is a long way to go regarding the "Strategic Impact Goals for 2030 and Beyond" issued by the American  
75 Heart Association (AHA).

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5 76 Previous studies have suggested that an ideal CVH is negatively associated with age-related diseases. (9) Sarcopenia, marked  
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7 77 by the age-related loss of muscle mass, strength, and function, has become a severe medical problem in the current aging society.  
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9 78 A meta-analysis indicated that patients with sarcopenia have decreased function, and higher rates of falls and hospitalization. (10)  
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11 79 Sarcopenia shares many common pathogenic mechanisms with CVDs, such as hormonal changes, inflammation and oxidative stress.  
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14 80 (11) Studies have confirmed that sarcopenia is significantly associated with increased cardiovascular events or mortality, (12) and  
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16 81 patients with CVDs are also more likely to develop sarcopenia than age-matched controls. (13)  
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18 82 Although several studies have explored the relationship between cardiovascular risk factors and sarcopenia, (14) it remains  
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21 83 unclear whether ideal CVH metrics are beneficial in sarcopenic populations.  
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23 84 This study aimed to determine the relationship between CVH and sarcopenia by using the 2011-2018 National Health and  
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25 85 Nutrition Examination Survey (NHANES) data to contribute to the accomplishment of the AHA 2030 goals.  
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## 29 30 87 **Methods**

### 31 32 88 **Patient and public involvement**

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34 89 NHANES is a nationally representative health survey designed and administered by the National Center for Health Statistics (NCHS)  
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37 90 at the Centers for Disease Control and Prevention (CDC) and was approved by the NCHS Research Ethics Review Board (protocols  
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5 91 Numbers: NHANES Protocol #2011-17 and NHANES Protocol #2018-01). The NHANES was designed to represent the civilian non-  
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7 92 institutionalized United States population using a complex multistage probability sampling methodology. We conducted a  
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9 93 retrospective analysis of a cohort of US population of the NHANES from 2011 to 2018. Written informed consent was acquired from  
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11 94 each NHANES participant. The NHANES includes extensive demographic data, physical examinations, laboratory tests, health-  
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13 95 related questionnaires and lists of prescription medications, which were measured at the start of the study. Further details on the data  
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15 96 collection procedure and analytical guidelines are publicly available on the NHANES website. (15) As shown in **Figure S1**, this study  
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17 97 included participants with reliable first 24-h dietary recall and  $\geq 20$  years of age during NHANES 2011-2018 (n = 21,128). Of these  
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19 98 participants, 11,802 were excluded based on the following: (i) no reliable dual-energy X-ray absorptiometry (DXA) and body mass  
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21 99 index (BMI) data; and (ii) insufficient data to calculate the CVH scores. Thus, 9,326 participants were enrolled in the present study.  
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### 101 **DXA, appendicular skeletal muscle mass, and the definition of sarcopenia**

102 DXA whole-body scans were performed on participants 8-59 years of age using Hologic Discovery model A densitometers (Hologic,  
103 Inc., Bedford, MA, USA). DXA exclusion criteria included pregnancy, weight >300 pounds (136 kg, because of the weight limit of the  
104 scanner), height > 6'5" (DXA table limitations), history of radiographic contrast material (barium) used in the past 7 days, or nuclear  
105 medicine studies in the past 3 days. Hologic software (version 8.26: a3\*) was used to administer all scans.

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5 106 Appendicular skeletal muscle mass was measured using DXA. The sarcopenia index was calculated as follows: sarcopenia index  
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7 107 = total appendicular skeletal muscle mass (in kg)/BMI (kg/m<sup>2</sup>).  
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9 108 Sarcopenia was defined as the lowest for sex-specific sarcopenia index cut-off values (0.789 for men and 0.512 for women),  
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11 based on the National Institutes of Health (FNIH).  
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### 16 111 **CVH metrics**

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18 112 CVH metrics include four health behaviors (cigarette smoking, physical activity, healthy dietary scores, and BMI) and three health  
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20 factors (total cholesterol level, blood pressure, and fasting plasma glucose level). (5) The definitions of ideal, intermediate, and poor  
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22 CVH metrics for adults are presented in **Table 1**. We used the Healthy Eating Index 2010 (HEI-2010) scores as a proxy of healthy  
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24 dietary scores, which were calculated using first-day 24-h dietary recall. HEI-2010 scores were based on a 12-component index, with  
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26 total scores ranging from 0-100, and a higher score indicating a healthier diet: total fruit; whole fruit; total vegetables; grains and  
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28 beans; whole grains; dairy; total protein foods; seafood and plant protein; fatty acids; refined grains; sodium; and empty calories.  
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30 117 Participants with an HEI-2010 score  $\leq$  50 were assigned to poor health, those with a score of 51-80 to intermediate health, and those  
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32 with a score  $\geq$  81 to ideal health.  
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121 **Table 1. Distribution of ideal, intermediate and poor CVH for each metric for adults free of CVD, NHANES 2011-2018. (5)**

<b>AHA definitions of CVH for each metric</b>		<b>Total sample (n=9,326)</b>
<b>Smoking status, n (%)</b>		
Ideal	Never or quit >12 mo	7,003 (75.2)
Intermediate	Former ≤12 mo	216 (2.9)
Poor	Yes	2,107 (22.0)
<b>Body mass index, n (%)</b>		
Ideal	< 25 kg/m <sup>2</sup>	2,890 (31.1)
Intermediate	25-29.9 kg/m <sup>2</sup>	2,937 (32.6)
Poor	≥ 30 kg/m <sup>2</sup>	3,499 (36.3)
<b>Physical activity, n (%)</b>		
Ideal	≥150 min/wk moderate intensity or ≥75 min/wk vigorous intensity or ≥150 min/wk moderate+vigorous	3,660 (41.9)
Intermediate	1–149 min/wk moderate intensity or 1–74 min/wk vigorous intensity or 1–149 min/wk moderate+vigorous	625 (7.6)
Poor	None	5,041 (50.5)
<b>Healthy diet score *, n (%)</b>		
Ideal	4-5 components	201 (2.2)
Intermediate	2-3 components	4,046 (44.3)
Poor	0-1 components	5,079 (53.5)
<b>Total cholesterol, n (%)</b>		
Ideal	< 200 mg/dL	5,213 (54.1)
Intermediate	200–239 mg/dL or treated to goal	2,548 (28.7)
Poor	≥ 240 mg/dL	1,565 (17.2)
<b>Blood pressure, n (%)</b>		
Ideal	<120/<80 mm Hg	4,474 (49.1)
Intermediate	SBP 120–139 or DBP 80–89 mm Hg or treated to goal	2,933 (31.9)
Poor	SBP ≥140 or DBP ≥90 mm Hg	1,919 (20.0)

**Glycated hemoglobin A1c, n (%)**

Ideal	< 5.7%	6,509 (76.0)
Intermediate	5.7%-6.4% or treated to goal	1,945 (16.8)
Poor	> 6.4%	875 (7.2)

**Abbreviation:** CVH, cardiovascular health; CVD, cardiovascular disease; NHANES, National Health and Nutrition Examination Survey; AHA, The American Heart Association; DBP, diastolic blood pressure; SBP, systolic blood pressure.

\* AHA's healthy diet score includes five components: fruits and vegetables, whole grain, fish, sodium, and sugar-sweetened beverage, and a very small proportion (<0.5%) of U.S. adults meet the ideal healthy diet. HEI-2010 is a continuous score consisting of 12 components representing major food groups including fruit and vegetables, whole grains, proteins, dairy, oils, sodium, and empty calories. HEI-2010 score ranges from 0 to 100 with a higher score indicates more healthy diet. HEI-2010 has been validated to represent the diet quality in population. We used HEI-2010 as a proxy for AHA's healthy diet score with ideal diet: HEI-2010  $\geq$  81; intermediate diet: 51-80; and poor diet:  $\leq$  50.

Although the AHA relies on fasting glucose to determine hyperglycemia, we use HbA1c (HbA1c) concentrations for two reasons.

First, recent recommendations from the American Diabetes Association allow the use of HbA1c to diagnose diabetes. Second, a significant percentage of NHANES participants who took the test did not fast. Therefore, we used HbA1c values < 5.7%, 5.7%-6.4%, and  $\geq$  6.5% as a proxy for fasting plasma glucose levels < 100 mg/dL, 100 to < 126 mg/dL, and  $\geq$  126 mg/dL. Participants who reported having diabetes or being treated with insulin or an oral medication to lower blood glucose and had an HbA1c concentration between 5.7% and 6.4% were categorized as intermediate health. Similarly, participants who reported taking cholesterol-lowering or antihypertensive medications and were treated to goal were categorized as "intermediate," whereas participants with these conditions who were untreated or who were not treated to goal were categorized as "poor" for that health factor. Use of antihypertensive, cholesterol-lowering, and glucose-lowering medications were self-reported. Total cholesterol and plasma glucose levels were

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5 140 measured with enzymatic methods (<https://www.cdc.gov/nchs/nhanes/index.htm>). BMI was calculated as the weight in kilograms  
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7 141 divided by the height in meters squared. The mean blood pressure was estimated from up to three readings obtained under standard  
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9 142 conditions during a single physical examination.  
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12 143 For each metric, participants received 0, 1, or 2 points, representing poor, intermediate, or ideal categories, respectively.  
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14 144 Participants with overall scores of 0-7, 8-11, or 12-14 points were categorized as having poor, intermediate, or ideal CVH, respectively.  
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16 145 Owing to the relatively low number of people with an ideal CVH score in this sample, the intermediate and ideal CVH categories were  
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18 146 combined.  
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## 22 23 148 **Statistical analysis**

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25 149 We used the NHANES recommended weights to account for planned oversampling of specific groups. The continuous variables were  
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28 150 expressed as the mean  $\pm$  standard error, and the categorical variables were presented as counts (percentages). Baseline  
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30 151 characteristics between the two CVH groups were compared using a t-test for continuous variables and a  $\chi^2$  test for categorical  
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32 152 variables.  
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35 153 Multiple logistic regression was used to examine the independent influence of CVH on sarcopenia comparing poor CVH versus  
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37 154 intermediate or ideal CVH after adjustments for potential confounders, such as age, sex, and race/ethnicity, educational level, alcohol,  
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5 155 congestive heart failure, coronary heart disease, angina and cancer. The odds ratio (OR) and 95% confidence interval (CI) were  
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7 156 computed. We explored the relationship between CVH and sarcopenia in different subgroups (age, sex, race/ethnicity and education  
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9 157 level). We also separately estimated the association between individual components of the CVH metrics and sarcopenia. When  
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11 158 assessing the role of individual components, the age, sex, and race/ethnicity, educational level, alcohol, congestive heart failure,  
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13 159 coronary heart disease, angina and cancer were adjusted. Furthermore, we used multiple logistic regression analysis to assess the  
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15 160 effect of a different number of ideal cardiovascular health metrics (ICVHMs) on the incidence of sarcopenia. A two-sided *P*-value <  
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17 161 0.05 indicated significance for all analyses. All data analyses were performed using SAS Release 9.4 (SAS Institute) and Survey  
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19 162 package in R software (version 4.0.4; R Foundation for Statistical Computing, Vienna, Austria).  
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## 25 164 **Results**

### 26 165 **Baseline characteristics**

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30 166 This study shown that only 2.2% of the participants met the ideal diet criteria. The frequency in the present sample of participants  
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32 167 meeting the ideal level for the remainder of CVH metrics were cigarette smoking (weighted, 75.2%), HbA1c (weighted, 75.2%), total  
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34 168 cholesterol level (weighted, 54.1%), blood pressure (weighted, 49.1%), physical activity (weighted, 41.9%), and BMI (weighted, 31.1%)  
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37 169 **(Table 1)**.  
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5 170 This cohort study involved 9,326 adults  $\geq$  20 years of age, comprising 4,733 females (weighted, 50.0%) and 4,593 males  
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7 171 (weighted, 50.0%), with a weighted mean (SE) age of  $39.3 \pm 0.3$  years. 3,323 (weighted, 60.3%) were of non-Hispanic white ancestry,  
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9 172 967 (weighted, 7.3%) of Hispanic ancestry, and 1,955 (weighted, 11.3%) of non-Hispanic Black ancestry. The study population  
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11 173 characteristics are listed in **Table 2** by CVH metrics. The number of intermediate or ideal and CVH participants was 5,654 and 3,672,  
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14 174 with mean CVH metrics of  $9.7 \pm 0.0$  and  $5.7 \pm 0.0$ , respectively. The differences of CVH metrics were significant for age, race/ethnicity,  
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16 175 and education ( $P < 0.001$ ). The frequency in the present sample of sarcopenia in participants with poor CVH metrics was 12.3%,  
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18 176 nearly three-fold as participants with intermediate or ideal CVH metrics (4.8%). Moreover, we analyzed the characteristics of this  
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20 177 study population by sarcopenic status. Sarcopenia was identified in 45.9% of 403 females based on the sarcopenia criteria and the  
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22 178 non-Hispanic white ancestry more like to develop sarcopenia (47.5%) compared with other races/ethnicities. Furthermore, the patient  
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24 179 with sarcopenia had poor education level, BMI risk, healthy diet score risk, blood pressure risk, HbA1c risk, and overall CVH metrics.  
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28 180 And more detailed analyses are presented in **Table S1**.  
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**Table 2. Baseline characteristics of the study population**

Characteristics	Total (n=9,326)	Intermediate or Ideal CVH (n=5,654)	Poor CVH (n=3,672)	P value
Age, mean (SE), years	39.3 (0.3)	36.4 (0.3)	44.3 (0.3)	< 0.001
Female, n (%)	4,733 (50.0)	2,933 (50.9)	1,800 (48.5)	0.078

<b>Race/ethnicity, n (%)</b>				
Mexican American	1,406 (11.1)	846 (11.4)	560(10.5)	
Other Hispanic	967 (7.3)	598 (7.5)	369 (7.0)	
Non-Hispanic White	3,323 (60.3)	2,067 (61.3)	1,256 (58.5)	< 0.001
Non-Hispanic Black	1,955 (11.3)	1,001 (9.5)	954 (14.7)	
Other	1,675 (9.9)	1,142 (10.3)	533 (9.3)	
<b>Heavy use of alcohol, n (%) *</b>				
< 12	6,636 (97.8)	4,111 (98.5)	2,525 (96.6)	
≥ 12	156 (2.2)	75 (1.5)	81 (3.4)	0.173
<b>Education levels, n (%)</b>				
< 12	3,675 (34.6)	1,989 (31.0)	1,686 (40.9)	
12	3,092 (34.0)	1,863 (33.6)	1,299(34.6)	< 0.001
> 12	2,557 (31.4)	1,800 (35.4)	757 (24.5)	
<b>Scores of CVH metrics, mean (SE)</b>				
No	8.24 (0.04)	9.70 (0.03)	5.66 (0.04)	< 0.001
<b>Congestive heart failure</b>	8,519 (92.5)	5,326 (95.2)	3,193 (87.7)	
<b>Coronary heart disease</b>	97 (1.0)	23 (0.2)	74 (1.8)	< 0.001
<b>Angina</b>	92 (1.0)	17 (0.2)	75 (2.2)	< 0.001
<b>Cancer</b>	94 (1.0)	30 (0.4)	64 (2.2)	< 0.001
<b>Sarcopenia, n (%)</b>	349 (5.0)	158 (3.9)	191 (6.8)	< 0.001
Yes	807 (7.5)	328 (4.8)	479 (12.3)	
No	8,519 (92.5)	5,326 (95.2)	3,193 (87.7)	< 0.001

183 **Abbreviation:** CVH, cardiovascular health.

184 \* Data missing > 5%

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187 **Association between CVH metrics and sarcopenia**

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5 188 The intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (odds ratio [OR]: 0.36 0.29-0.44,  
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7 189  $P < 0.001$ ; **Table 3**). After adjusting for age, sex, race/ethnicity, education level, alcohol use, congestive heart failure, coronary heart  
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9 190 disease, angina and cancer, intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (adjusted  
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11 191 odds ratio [aOR]: 0.36, 95% CI: 0.26-0.50,  $P < 0.001$ ). In the fully adjusted model, the odds of sarcopenia were significantly lower for  
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13 192 each incremental increase of 1 in CVH metrics (aOR: 0.75, 95% CI: 0.71-0.79,  $P < 0.001$ ). Further stratified and interaction analyses  
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15 193 were performed for age, sex, race/ethnicity, and education level. And the association between intermediate or ideal CVH and  
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17 194 sarcopenia was significant in different subgroups. Notably, the age group also showed stronger association in the subgroup aged  $<$   
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19 195 45 years (aOR: 0.38, 95% CI: 0.27-0.52,  $P < 0.001$ ). Further, among subgroups of non-Hispanic Black, the odds of sarcopenia  
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21 196 decreased by 79% in participants with intermediate or ideal CVH than in participants with poor CVH (aOR: 0.21, 95% CI: 0.08-0.50,  
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23 197  $P = 0.038$ ; aOR: 0.24, 95%CI: 0.09-0.66,  $P < 0.001$ ; Table 3). For all of subgroups, there was no significant interaction (all  $P$  for  
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25 198 interaction  $> 0.05$ ), expect of education levels ( $P$  for interaction= 0.014).  
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201 **Table 3. The association between CVH metrics and Sarcopenia by selected subgroups**

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Variable	No. (%)	Intermediate or Ideal CVH OR (95%CI) †	P value	Intermediate or Ideal CVH OR (95%CI) *	P value	P for interaction
<b>Continuous</b>						
CVH (per 1 score)	807/9,326	0.77 (0.74-0.79)	<0.001	0.75 (0.71-0.79)	<0.001	-
<b>Categories †</b>						
Poor CVH	479/3,672	1[Ref]	-	1[Ref]	-	-
Intermediate or Ideal CVH	328/5,654	0.36 (0.29-0.44)	<0.001	0.36 (0.26-0.50)	<0.001	-
<b>Subgroup</b>						
<b>Age</b>						
<45	211/4,200	0.41 (0.31-0.54)	<0.001	0.38 (0.27-0.52)	<0.001	0.189
45-59	117/1,454	0.37 (0.27-0.52)	<0.001	0.32 (0.19-0.53)	<0.001	
<b>Sex</b>						
Male	157/2,721	0.33 (0.24-0.45)	<0.001	0.36 (0.24-0.53)	<0.001	0.827
Female	171/2,933	0.40 (0.30-0.54)	<0.001	0.35 (0.21-0.58)	<0.001	
<b>Race</b>						
Mexican American	127/864	0.41 (0.28-0.60)	<0.001	0.43 (0.28-0.67)	<0.001	0.704
Other Hispanic	44/598	0.32 (0.18-0.58)	<0.001	0.37 (0.20-0.70)	0.003	
Non-Hispanic White	80/2,067	0.30 (0.22-0.40)	0.019	0.31(0.17-0.56)	<0.001	

Non-Hispanic Black	8/1001	0.15 (0.07-0.32)	<0.001	0.21 (0.08-0.50)	<0.001	
Other	69/1,142	0.40 (0.23-0.69)	0.001	0.45 (0.22-0.95)	0.036	
<b>Education levels</b>						
<12	179/1,989	0.43 (0.33-0.57)	<0.001	0.49 (0.33-0.74)	<0.001	
12	87/1,863	0.39 (0.25-0.61)	<0.001	0.32 (0.19-0.54)	<0.001	0.014
>12	62/1,800	0.30 (0.18-0.50)	<0.001	0.20 (0.10-0.40)	<0.001	

202 **Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

203 † Unadjusted model.

204 \* Analyses were adjusted for age, sex, race/ethnicity, education level, alcohol use, congestive heart failure, coronary heart disease,  
205 angina and cancer.

206 Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.

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### 208 **Association between number of ICVHMs and sarcopenia**

209 21% of participants with sarcopenia had only 1 ICVHM and 5% had 5 ideal ICVHMs. In participants without sarcopenia, up to 70%  
210 had  $\geq 3$  ICVHMs (**Figure S2**). Logistic regression of the ICVHM number and the odds of sarcopenia revealed that the higher the  
211 number of ICVHMs, the lower the odds of sarcopenia. When participants had 3 ideal CVH metrics, the odds of sarcopenia decreased  
212 by 50% compared to participants with non-ideal CVH metrics (aOR: 0.50, 95% CI: 0.32-0.78). If the number of ICVHMs was  $\geq 5$ , the  
213 odds of sarcopenia decreased by up to 84% (aOR: 0.16, 95% CI: 0.08-0.30; **Figure 1**).

## 214 Association between different individual CVH components and sarcopenia

215 In the subgroup analysis of the seven individual CVH components, participants defined as intermediate or poor CVH had a higher  
 216 odds of sarcopenia odds than those with ideal CVH in all CVH metric subgroups except for the subgroup with cigarette smoking  
 217 status, total cholesterol, and physical activity. Especially in the BMI and healthy diet score subgroups, the odds of sarcopenia  
 218 decreased > 80% (BMI: [aOR: 0.08, 95% CI: 0.05-0.13,  $P < 0.001$ ]; healthy diet score: [aOR: 0.18, 95% CI: 0.06-0.54,  $P = 0.005$ ]). A  
 219 decreasing odd of sarcopenia trends were observed between increasing levels of CVH components for BMI, healthy diet score,  
 220 HbA1c and blood pressure (all  $P$  for trend < 0.05; **Table 4**).

222 **Table 4. Adjusted odds ratios (95% CI) of Sarcopenia by individual component of CVH Metrics.**

Variable	OR *	95%CI	P value	P for trend
<b>Smoking status</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.84	0.33-2.12	0.706	0.201
Ideal	1.25	0.87-1.80	0.223	
<b>Body mass index</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.21	0.16-0.29	<0.001	<0.001
Ideal	0.08	0.05-0.13	<0.001	
<b>Healthy diet score</b>				

Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.66	0.46-0.93	0.019	0.005
Ideal	0.18	0.06-0.54	0.003	
<b>Total cholesterol</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.91	0.62-1.36	0.650	0.054
Ideal	0.68	0.45-1.03	0.069	
<b>Glycated hemoglobin A1c</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.37	0.21-0.63	0.001	<0.001
Ideal	0.28	0.14-0.36	< 0.001	
<b>Physical activity</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.93	0.56-1.54	0.774	0.401
Ideal	0.89	0.67-1.18	0.402	
<b>Blood pressure</b>				
Poor	1[Ref]	1[Ref]	NA	
Intermediate	0.62	0.43-0.89	0.010	<0.001
Ideal	0.37	0.26-0.52	<0.001	

223 **Abbreviations:** CVH, cardiovascular health; OR, odds ratio.

224 \* Analyses were adjusted for age, sex, race/ethnicity, education level, alcohol use, congestive heart failure, coronary heart disease,  
225 angina and cancer.

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## 227 Discussion

228 This study used nationwide, population-based, cross-sectional data to demonstrate a significant association between CVH and

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5 229 sarcopenia and showed a significantly 64% decreased adjusted risk of sarcopenia in subjects with better CVH metrics. For each unit  
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7 230 increase in the metrics of CVH, the risk of CVDs decreased by 25%. Furthermore, higher intermediate or ideal CVH metrics were  
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9 231 associated with a lower prevalence of sarcopenia.

11 232 Our study yielded several interesting findings. First, the CVH metrics were not only associated with CVDs, but also non-CVDs,  
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13 233 including sarcopenia. This result agreed with Han et al., (16) who also reported that sarcopenia was independently associated with  
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15 234 cardiovascular risk factors, including diabetes and hypertension. And these risk factors were shown to be associated with the  
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17 235 prevalence of sarcopenia defined by the recommended algorithm of the Asian Working Group in the Chinese elderly. (14) However,  
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19 236 these results may only be applicable in patient with high-risk cardiovascular risk factors. In order to explore the association between  
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21 237 sarcopenia and the common individual with average or only slightly unfavorable levels of risk factors, we chose CVH and elaborated  
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23 238 on the detail and found that higher intermediate or ideal CVH metrics were associated with a lower prevalence of sarcopenia, as  
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25 239 defined by the recommended algorithm of the FNIH in American adults. This finding suggests that the level of CVH influences the  
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27 240 incidence of sarcopenia and emphasizes the greater importance of CVH for health care and medical conditions. A previous study  
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29 241 showed that the presence of more desirable CVH indicators was associated with a significant reduction in CVD morbidity and mortality  
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31 242 (17). Our study broadens the application value of the CVH metrics; specifically, the higher the number of intermediate or ideal CVH  
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33 243 metrics, the lower the incidence of sarcopenia. It showed that only a small percentage of American adults met the ideal criteria for 6  
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5 244 or 7 ideal health metrics. This result is disappointing, but perhaps not surprising. Furthermore, this result challenges clinical and public  
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7 245 health professionals to keep steering the health metrics in the desired direction. In the meantime, additional research is warranted in  
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9 246 the future to explore CVH and non-cardiovascular fields to increase public awareness of CVH and promote achievement of AHA  
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11 247 2030 goals.

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14 248 Second, we further observed the effects of CVH metrics on sarcopenia in different subgroups. We have reported that CVH  
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16 249 influences the incidence of sarcopenia not only in the elderly population, (14) but in the younger population. In addition, we  
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18 250 demonstrated similar results in the sex and ethnicity subgroups. Surprisingly, it appeared that the ideal CVH metrics affect different  
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20 251 levels of participant with different levels of education. Recent study shown that low education compared to high education was  
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22 252 associated with lower odds of having ideal CVH (18). However, it appears that participants with higher levels of education are able  
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24 253 to benefit more from the ideal CVH. At the same time, participants with low education levels also reduced the prevalence of sarcopenia  
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26 254 by nearly 50% from the ideal CVH. Therefore, we not only need to focus on the ideal level of CVH for participants with low education  
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28 255 levels, but also need to further increase the attainment rate of ideal CVH for participation with high education levels to achieve further  
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30 256 benefits.

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34 257 Third, we attempted to determine the effect of each indicator in CVH alone on sarcopenia in this study. Our study showed that  
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36 258 reduced HbA1c levels were associated with a decreased risk of sarcopenia. This was consistent with the results of previous studies.  
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5 259 (19) This finding may be attributed to the fact that higher blood glucose levels accelerate the loss of muscle mass and strength. (20)  
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7 260 In addition, ideal blood pressure was the second significant feature associated with sarcopenia. Han P et al. (14) also found that  
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9 261 hypertension is an independent risk factor for sarcopenia. Although the mechanism underlying sarcopenia and hypertension is  
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11 262 currently unknown, recent studies have concluded that inflammatory factors during aging could impair blood flow by damaging the  
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13 263 microvascular endothelium, (21) which exerted a detrimental effect on the body of the elderly. Additional studies are needed to  
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15 264 elucidate the causal relationship between hypertension and sarcopenia. Healthy eating is significantly associated with sarcopenia.  
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18 265 The Papaioannou study (22) highlighted the beneficial link between healthy eating and sarcopenia risk. There are several possible  
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20 266 mechanisms to explain the beneficial effects of a healthy diet on skeletal muscle. First, a healthy diet rich in fruits and vegetables  
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22 267 prevents metabolic acidosis and reduces protein hydrolysis and amino acid catabolism, thus reducing the risk of sarcopenia. (23) In  
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24 268 addition, unfavorable dietary patterns, including foods rich in saturated fats, may be detrimental to the maintenance of muscle health,  
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26 269 (24) while a fiber-rich diet reduces the risk of sarcopenia. (25) Some studies, however, suggest that a lower BMI indicates the  
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28 270 presence of sarcopenia and malnutrition and is associated with higher mortality in the older population. (26) Conversely, obese  
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30 271 patients may have a survival benefit. (27) However, our study still found that being overweight or obese can significantly increase the  
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32 272 risk of sarcopenia. The poor prediction of physical activity in the present study was unexpected, in contrast to previous studies (28)  
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34 273 that suggested only ideal physical activity does appear to be associated with the onset of sarcopenia. This finding might be due to  
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5 274 the population in our study cohort included only young and middle-aged adults. Physical activity may be crucial for the occurrence of  
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7 275 sarcopenia in the elderly population.

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9 276 Our study has several limitations. First and foremost, cigarette smoking, physical activity, diseases, and diet were self-reported,  
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11 277 and subjected to misclassification and recall bias, which can lead to an over- or under-estimated association between CVH and  
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13 278 sarcopenia. Second, as noted above, for practical reasons, we were not fully compliant with all of the AHA 2020 health indicators.  
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15 279 Moreover, our study was cross-sectional, so the association between CVH and sarcopenia cannot be interpreted as a direct cause-  
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17 280 and-effect relationship. Finally, a half of initial cohort has been excluded in this study, which will increase the variance of the odds  
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19 281 ratio estimates. However, our results are still relatively reliable after weighting, since the main missing data are due to missing  
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## 26 27 28 284 **Conclusion**

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30 285 In conclusion, our findings suggested a relationship between CVH indicators and the prevalence of sarcopenia among US adults.  
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32 286 Our analysis confirms that CVH extends beyond protection against cardiovascular disease. More research is needed to clarify the  
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34 287 association between CVH and other non-CVDs. The results of our study can help facilitate the 2030 goal of achieving CVH for all  
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36 288 because the AHA 2030 goal may be supported by efforts to reduce the prevalence of sarcopenia.  
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7 290 **Contributorship**

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9 291 The authors' contributions were as follows; WHC: participated in formulating the research question, design of analyses, interpretation  
10 292 of the data, drafting the manuscript, revising the manuscript, and the approval of the final version; SSS: participated in the design of  
11 293 analyses, data analysis, revising the manuscript, and approval of the final version; YZJ: drafting the manuscript, revising the  
12 294 manuscript, and the approval of the final version; YL: interpretation of the data and the approval of the final version; KHC: participated  
13 295 in formulating the research question, design of analyses, revising the manuscript, and the approval of the final version; RCH:  
14 296 participated in formulating the research question, design of analyses, data analysis, interpretation of the data, and the approval of  
15 297 the final version; KH: participated in formulating the research question, design of analyses, data analysis, interpretation of the data,  
16 298 and the approval of the final version; and all authors: read and approved the final version of the manuscript and are responsible for  
17 299 all aspects of the manuscript.

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7 305 **Competing interests**

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9 306 WHC, SSS, YZJ, YL, KHC, RCH and KH report no conflicts of interest.

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14 308 **Ethics approval**

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16 309 NHANES was approved by the NCHS Research Ethics Review Board (protocols Numbers: NHANES Protocol #2011-17 and

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18 310 NHANES Protocol #2018-01).

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23 312 **Data sharing statement**

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25 313 None

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9 Association between number of ICVHMs and sarcopenia.  
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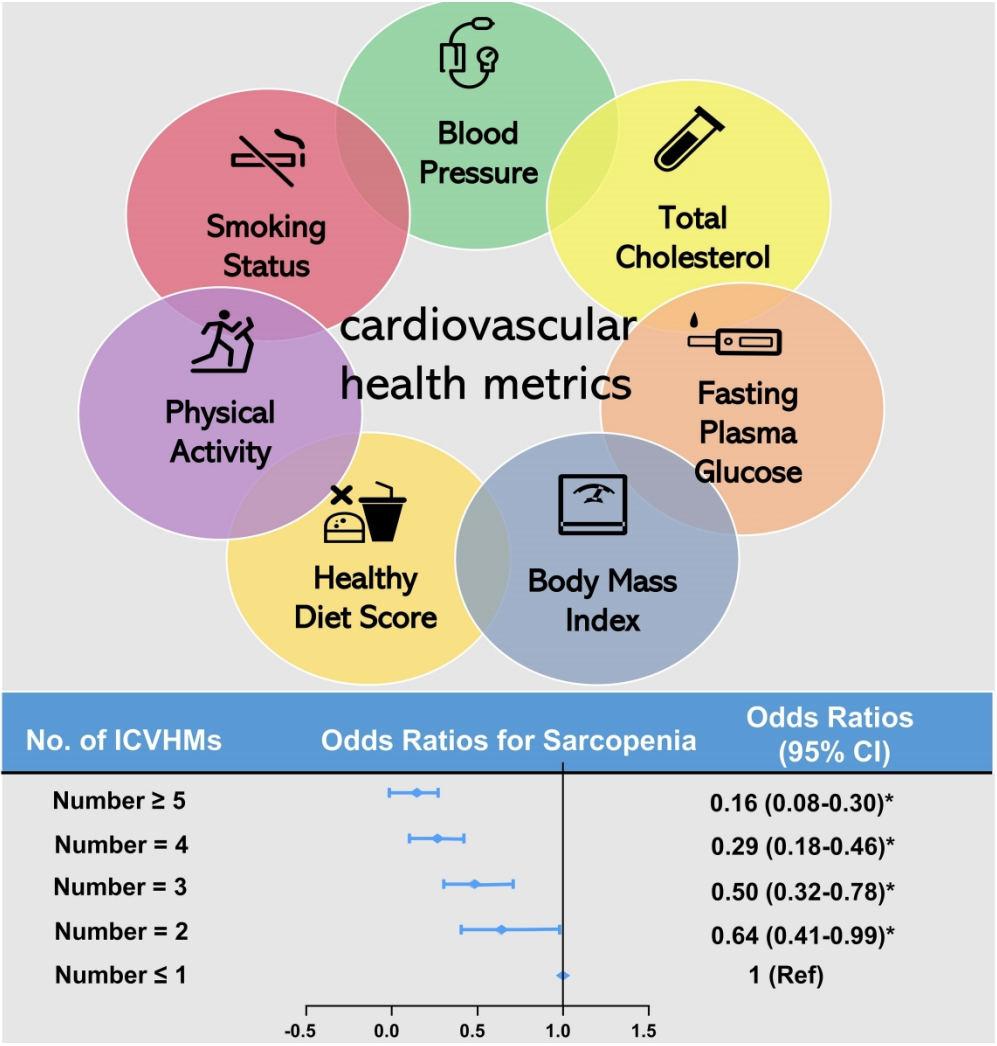
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12 **Legend to Figure 1**

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14 Abbreviation: ICVHMs, Ideal cardiovascular health metrics.

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16 Model: Adjusted by age, sex, and race/ethnicity, educational level, alcohol use, congestive heart failure, coronary heart disease,  
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18 angina and cancer.  
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21 \*  $P < 0.05$ .  
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Association between number of ICVHMs and sarcopenia.

345x358mm (300 x 300 DPI)

**Table S1 Baseline characteristics of the study population by sarcopenic.**

<b>Characteristics</b>	<b>Non-sarcopenic (n=8519)</b>	<b>Sarcopenic (n=807)</b>	<b>p-value</b>
<b>Age, mean (SE), years</b>	39.0 (0.3)	42.9 (0.6)	0.002
<b>Female, n (%)</b>	4330 (50.3)	403 (45.9)	0.060
<b>Race/ethnicity, n (%)</b>			
Mexican American	1124 (9.9)	282 (26.1)	
Other Hispanic	846 (6.9)	121 (12.0)	
Non-Hispanic White	3103 (61.3)	220 (47.4)	< 0.001
Non-Hispanic Black	1905 (11.9)	50 (3.4)	
Other	1541 (9.9)	134 (11.1)	
<b>Heavy use of alcohol, n (%)</b>			
<12	6174 (97.9)	426 (95.8)	
≥12	135 (2.1)	21 (4.2)	0.026
<b>Education level, n (%)</b>			
Less Than High School	3214 (33.2)	461 (52.0)	
High School Diploma	2878 (34.1)	214 (32.2)	< 0.001
More Than High School	2425 (32.7)	132 (15.8)	
<b>Smoking risk, n (%)</b>			
Ideal	1969 (22.2)	138 (18.8)	
Intermediate	202 (2.9)	14 (1.8)	0.085
Poor	6348 (74.8)	655 (79.4)	
<b>Body mass index risk, n (%)</b>			
Ideal	2826 (33.1)	64 (6.5)	
Intermediate	2746 (33.5)	191 (21.1)	< 0.001
Poor	2947 (33.4)	525 (72.4)	

<b>Physical activity risk, n (%)</b>			
Ideal	3371 (42.1)	289 (39.1)	
Intermediate	579 (7.7)	46 (6.5)	0.274
Poor	4569 (50.2)	472 (54.4)	
<b>Healthy diet score risk, n (%)</b>			
Ideal	188 (2.3)	13 (1.0)	
Intermediate	3716 (44.7)	330 (38.8)	0.001
Poor	4615 (52.9)	464 (60.0)	
<b>Total cholesterol risk, n (%)</b>			
Ideal	4853 (54.8)	360 (45.7)	
Intermediate	2292 (28.4)	256 (32.1)	0.002
Poor	1374 (16.8)	191 (22.2)	
<b>Blood pressure risk, n (%)</b>			
Ideal	4203 (46.6)	271 (25.7)	
Intermediate	2650 (33.3)	283 (37.6)	< 0.001
Poor	1666 (20.1)	253 (36.8)	
<b>Fasting plasma glucose risk, n (%)</b>			
Ideal	6103 (50.4)	406 (32.3)	
Intermediate	1711 (31.8)	234 (33.9)	< 0.001
Poor	705 (17.8)	167 (33.8)	
<b>Scores of seven healthy metrics, mean (SE)</b>	8.4 (0.0)	6.8 (0.1)	< 0.001
<b>Overall CVH metrics, n (%)</b>			
Poor	3193 (34.3)	479 (59.3)	< 0.001
Intermediate or Ideal	5326 (65.7)	328 (40.7)	

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5 **Abbreviations:** CVH, cardiovascular health.

6 Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.  
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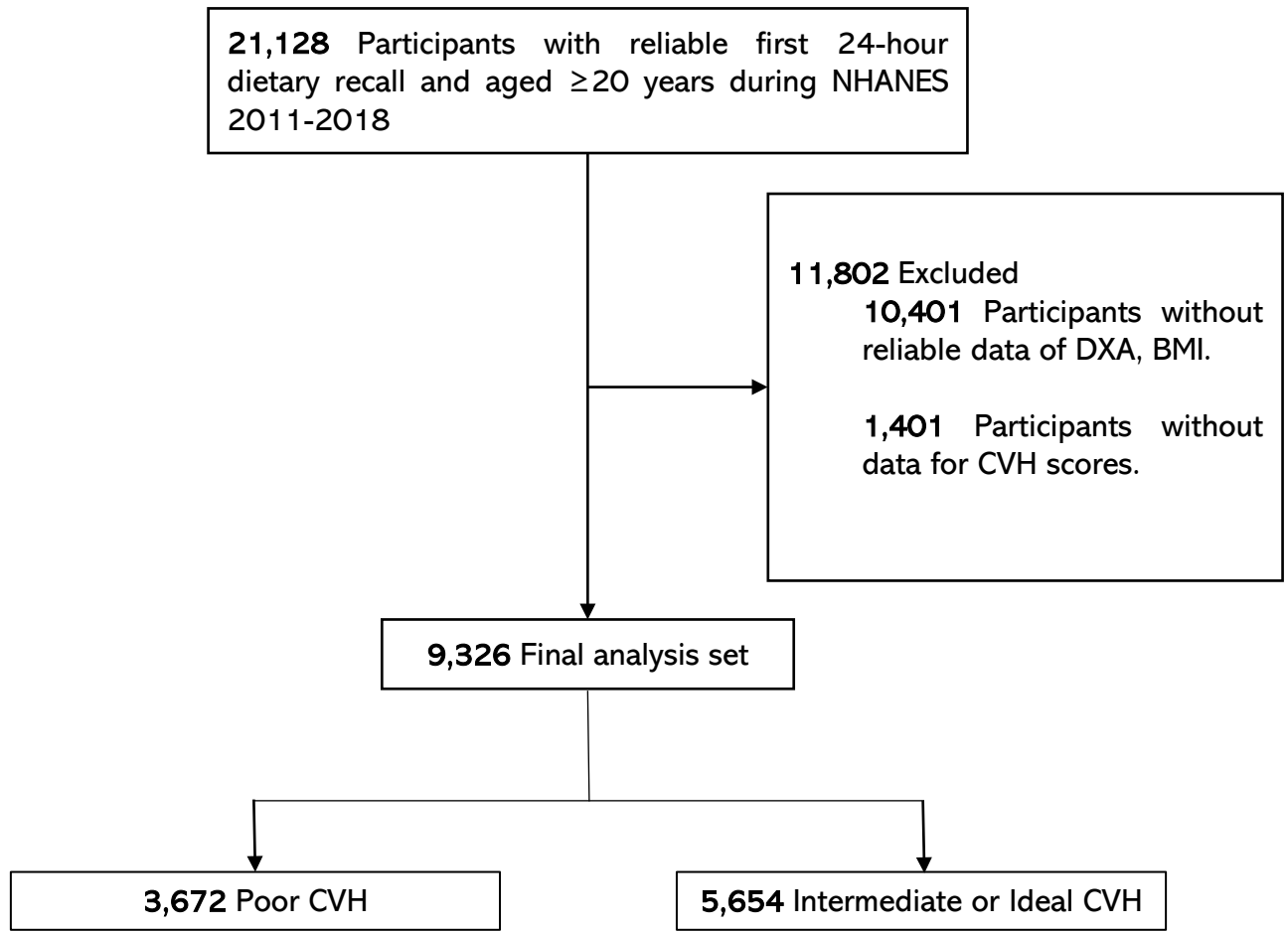


Figure S1. Flowchart.

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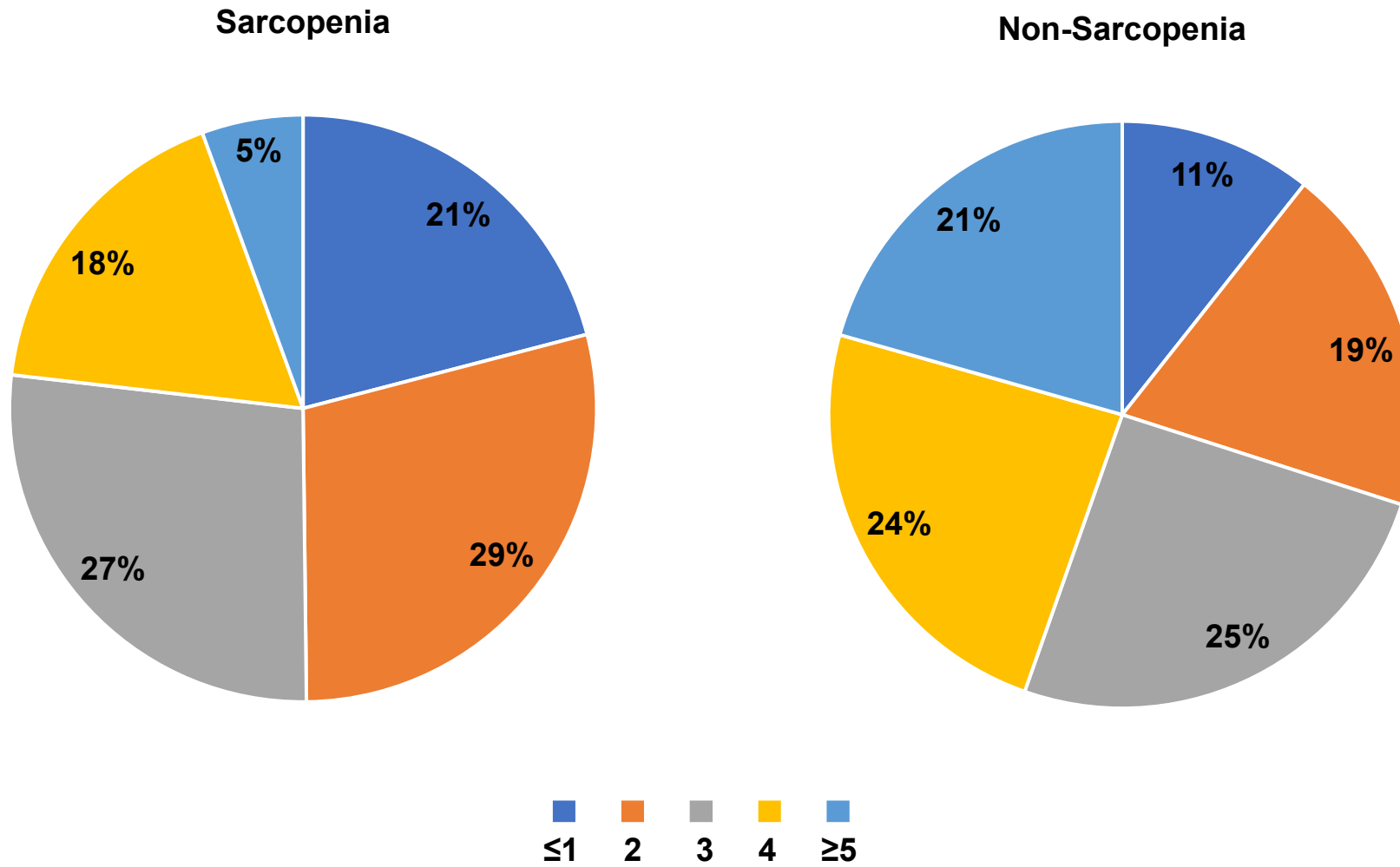


Figure S2. Proportion of IGVHMs in sarcopenia and non-sarcopenia.

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1, 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	23
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11-12
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	NA
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	NA
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11-12
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12 Table 2
		(b) Indicate number of participants with missing data for each variable of interest	NA



Outcome data	15*	Report numbers of outcome events or summary measures	Table 3
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-17
		(b) Report category boundaries when continuous variables were categorized	9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	18
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	19-20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	23
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20-21
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).