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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 ≥ 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 ± 0.06 and 5.43 ± 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).

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

Keywords: cardiovascular health metrics, sarcopenia, NHANES

Strengths and limitations of this study

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

This study suggests a relationship between the CVH and the prevalence of non-cardiovascular disease, sarcopenia. The results of our study 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 sarcopenia.

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

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

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-

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

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

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

Methods

Patient and public involvement

We conducted a retrospective analysis of a cohort of US population of the NHANES, a periodic survey performed by National Center for Health Statistics. Informed consent has been obtained from every participant and therefore there was no need for any ethical consent in this study. The NHANES includes extensive demographic data, physical examinations, laboratory tests, health-related questionnaires and lists of prescription

medications. As shown in **Figure 1**, this study included participants with reliable first 24-h dietary recall and ≥ 20 years of age during NHANES 2011-2018 (n = 21128). Of these participants, 17817 were excluded based on the following: (i) CVD (myocardial infarction, congestive heart failure, and stroke) and cancer; (ii) insufficient data to calculate the CVH scores; and (iii) no reliable dual-energy X-ray absorptiometry (DXA) and body mass index (BMI) data. Thus, 3311 participants were enrolled in the present study.

DXA, appendicular skeletal muscle mass, and the definition of sarcopenia

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

Appendicular skeletal muscle mass was measured using DXA. The sarcopenia index was calculated as follows: sarcopenia index = total appendicular skeletal muscle mass (in kg)/BMI (kg/m^2).

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 National Institutes of Health (FNIH).

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 ≤ 50 were assigned to poor health, those with a score of 51-80 to intermediate health, and those with a score ≥ 81 to ideal health.

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

AHA definitions of CVH for each metric		Total sample (n=3,311)
Smoking status, n (%)		
Ideal	Never or quit > 12 months ago	1212 (40.1)
Intermediate	Former ≤ 12 months	202 (7.2)
Poor	Current smoking	1897 (52.8)
Body mass index, n (%)		
Ideal	< 25 kg/m^2	1025 (30.3)
Intermediate	25-29.9 kg/m^2	1080 (33.8)
Poor	≥ 30 kg/m^2	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 *, 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-sweeten 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 from0 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;

intermediate diet: 51-80; and poor diet: ≤ 50.

To maximize the sample size, we used hemoglobin A1c (HbA1c) values < 5.7%, 5.7%-6.4%, and ≥ 6.5% as a proxy for fasting plasma glucose levels < 100 mg/dL, 100 to < 126 mg/dL, and ≥ 126 mg/dL, respectively, as recommended by the American Diabetes Association. 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 measured with enzymatic methods (https://www.cdc.gov/nchs/nhanes/index.htm). BMI was calculated as the weight in kilograms divided by the height in meters squared. The mean blood pressure was estimated from up to three readings obtained under standard conditions during a single physical examination.

For each metric, participants received 0, 1, or 2 points, representing poor, intermediate, or ideal categories, respectively. Participants with 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 low number of people with an ideal CVH score in this sample, the intermediate and ideal CVH categories were combined.

Statistical analysis

We used the NHANES recommended weights to account for planned oversampling of specific groups. The continuous variables were expressed

as the mean ± standard deviation, and the categorical variables were presented as counts (percentages). Baseline characteristics between the two CVH groups were compared using a t-test for continuous variables and a χ^2 test for categorical variables.

Multiple logistic regression was used to examine the independent influence of CVH on sarcopenia comparing poor CVH versus intermediate or ideal CVH after adjustments for potential confounders, such as age, sex, and race/ethnicity, educational level and alcohol. The odds ratio (OR) and 95% confidence interval (CI) were computed. We explored the relationship between CVH and sarcopenia in different subgroups (age, sex, race/ethnicity, education level and alcohol use). We also separately estimated the association between individual components of the CVH metrics and sarcopenia. When assessing the role of individual components, the age, sex, race/ethnicity, and education level were adjusted. Furthermore, we used multiple logistic regression analysis to assess the effect of a different number of ideal cardiovascular health metrics (ICVHMs) on the incidence of sarcopenia. A two-sided *P*-value < 0.05 indicated significance for all analyses. All data analyses were performed using SAS Release 9.4 (SAS Institute) and Survey package in R software (version 4.0.4; R Foundation for Statistical Computing, Vienna, Austria).

Results

Baseline characteristics

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

remainder of CVH metrics were cigarette smoking (40.1%), diabetes (75.8%), total cholesterol level (49.8%), blood pressure (45.2%), physical activity (44.5%), and BMI (30.3%) (**Table 1**).

This cohort study involved 3311 adults ≥ 20 years of age, comprising 1329 females (weighted proportion, 42.4%) and 1982 males (weighted, 47.6%), with a weighted mean (SE) age of 40.0 ± 0.4 years. 1477 (weighted, 66.6%) were of non-Hispanic white ancestry, 753 (weighted, 15.7%) of Hispanic ancestry, and 618 (weighted, 9.6%) of non-Hispanic Black ancestry. The study population characteristics are 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 9.3 ± 0.1 and 5.4 ± 0.1, respectively. The differences of CVH metrics were significant for age, race/ethnicity, and education ($P < 0.001$). The prevalence of sarcopenia in participants with poor CVH metrics was 9.9%, more than two times as participants with intermediate or ideal CVH metrics (3.6%).

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

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
Continuous				
CVH (per 1 score)	247/3311	0.76 (0.70-0.83)	<0.001	-
Categories †				
Poor CVH	180/1719	1[Ref]	-	-
Intermediate or Ideal CVH	67/1592	0.39 (0.22-0.69)	<0.001	-
Subgroup				
Age				
<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	
Sex				
Male	158/1982	0.43 (0.23-0.82)	0.014	0.539

Female	89/1329	0.30 (0.07-1.32)	0.117	
Race				
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	
Education levels				
<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 ≥ 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 ≥ 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
Smoking status				
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	
Body mass index				
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	
Healthy diet score				

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	
Total cholesterol				
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	
Fasting plasma glucose				
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	

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

showed a significantly 60% decreased adjusted risk of sarcopenia in subjects with better CVH metrics. For each unit increase in the metrics of CVH, the risk of CVDs decreased by 24%. Furthermore, higher intermediate or ideal CVH metrics were associated with a lower prevalence of sarcopenia.

Our study yielded several interesting findings. First, the CVH metrics were not only associated with CVDs, but also non-CVDs, including sarcopenia. This result agreed with Han et al., [15] who also reported that sarcopenia was independently associated with cardiovascular risk factors, including diabetes and hypertension. And these risk factors were shown to be associated with the prevalence of sarcopenia defined by the recommended algorithm of the Asian Working Group in the Chinese elderly. [14] However, these results may only be applicable in patient with high-risk cardiovascular risk factors. In order to explore the association between sarcopenia and the common individual with average or only slightly unfavorable levels of risk factors, we chose CVH and elaborated on the detail and found that higher intermediate or ideal CVH metrics were associated with a lower prevalence of sarcopenia, as defined by the recommended algorithm of the FNIH in American adults. This finding suggests that the level of CVH influences the incidence of sarcopenia and emphasizes the greater importance of CVH for health care and medical conditions. A previous study showed that the presence of more desirable CVH indicators was associated with a significant reduction in CVD morbidity and mortality [16]. Our study broadens the application value of the CVH metrics; specifically, the higher the number of intermediate or ideal CVH metrics, the lower the incidence of sarcopenia. It showed that only a small percentage of American adults met the ideal criteria for 6 or 7 ideal health metrics. This result is disappointing, but perhaps not surprising. Furthermore, this result challenges clinical

and public health professionals to keep steering the health metrics in the desired direction. In the meantime, additional research is warranted in the future to explore CVH and non-cardiovascular fields to increase public awareness of CVH and promote achievement of AHA 2030 goals.

Second, we further observed the effects of CVH metrics on sarcopenia in different subgroups. We have reported that CVH influences the incidence of sarcopenia not only in the elderly population, [14] but in the younger population. In addition, we demonstrated similar results in the ethnicity subgroups. Surprisingly, it appeared that poor CVH metrics in females did not affect the prevalence of sarcopenia. However, we found that the effect of CVH metrics was even stronger in young and middle-aged females than in males. Sex differences in antioxidant status may have contributed to this phenomenon. Earlier studies demonstrated significant sex-dependent differences in GPx (selenoproteins, such as GPx-1 and GPx-3) activity, [17] while postmenopausal females have relatively high levels of systemic oxidative stress. [18] This finding suggests that younger female may have higher levels of antioxidant enzymes and poor CVH metrics may significantly disrupt the antioxidant levels, and thus make the individual more susceptible to sarcopenia.

Third, we attempted to determine the effect of each indicator in CVH alone on sarcopenia in this study. Our study showed that reduced fasting plasma glucose levels were associated with a decreased risk of sarcopenia. This was consistent with the results of previous studies. [19] 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 blood pressure was the second significant feature associated with sarcopenia. Han P et al. [14] also found that hypertension is an independent risk factor for sarcopenia. Although the mechanism underlying sarcopenia and hypertension is currently unknown, recent studies have concluded

that inflammatory factors during aging could impair blood flow by damaging the microvascular endothelium, [21] which exerted a detrimental effect on the body of the elderly. Additional studies are needed to elucidate the causal relationship between hypertension and sarcopenia. Healthy eating is significantly associated with sarcopenia. The Papaioannou study [22] highlighted the beneficial link between healthy eating and sarcopenia risk. There are several possible mechanisms to explain the beneficial effects of a healthy diet on skeletal muscle. First, a healthy diet rich in fruits and vegetables prevents metabolic acidosis and reduces protein hydrolysis and amino acid catabolism, thus reducing the risk of sarcopenia. [23] In addition, unfavorable dietary patterns, including foods rich in saturated fats, may be detrimental to the maintenance of muscle 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 sarcopenia and malnutrition and is associated with higher mortality in the older population. [26] Conversely, obese patients may have a survival benefit. [27] However, our study still found that being overweight or obese can significantly increase the risk of sarcopenia. The poor prediction of physical activity in the present study was unexpected, in contrast to previous studies [28] that suggested only ideal physical activity does 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 middle-aged adults. Physical activity may be crucial for the occurrence of sarcopenia in the elderly population.

Our study has several limitations. First and foremost, cigarette smoking, physical activity, and diet were self-reported, and subjected to misclassification and recall bias, which can lead to an over- or under-estimated association between CVH and sarcopenia. Moreover, as noted above, for practical reasons, we were not fully compliant with all of the AHA 2020 health indicators. Finally, our study was cross-sectional, so

the association between CVH and sarcopenia cannot be interpreted as a direct cause-and-effect relationship.

Conclusion

In conclusion, our findings suggested a relationship between CVH indicators and the prevalence of sarcopenia among US adults. Our analysis confirms that CVH extends beyond protection against cardiovascular disease. More research is needed to clarify the association between CVH 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 supported by efforts to reduce the prevalence of sarcopenia.

Contributorship statement

The authors' contributions were as follows; WHC: participated in formulating the research question, design of analyses, interpretation of the data, drafting the manuscript, revising the manuscript, and the approval of the final version; SSS: participated in the design of analyses, data analysis, revising the manuscript, and approval of the final version; YZJ: drafting the manuscript, revising the manuscript, and the approval of the final version; YL: interpretation of the data and the approval of the final version; KHC: participated in formulating the research question, design of analyses, revising the manuscript, and the approval of the final version; RCH: participated in formulating the research question, design of analyses, data analysis, interpretation of the data, and the approval of the final version; KH: participated in formulating the research question,

design of analyses, data analysis, interpretation of the data, and the approval of the final version; and all authors: read and approved the final version of the manuscript and are responsible for all aspects of the manuscript.

Competing interests

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

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Data sharing statement

None

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Figure Legend

Title to Figure 1

Flowchart.

Title to Figure 2

Proportion of ICVHMs in sarcopenia and non-sarcopenia.

Title to Figure 3

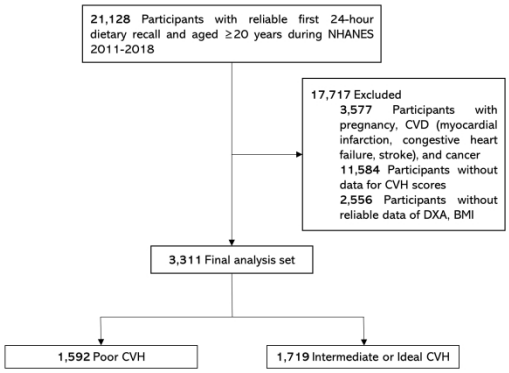
Association between number of ICVHMs and sarcopenia

Legend to Figure 3

Abbreviation: ICVHMs, Ideal cardiovascular health metrics.

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

* $P < 0.05$.



Flowchart.

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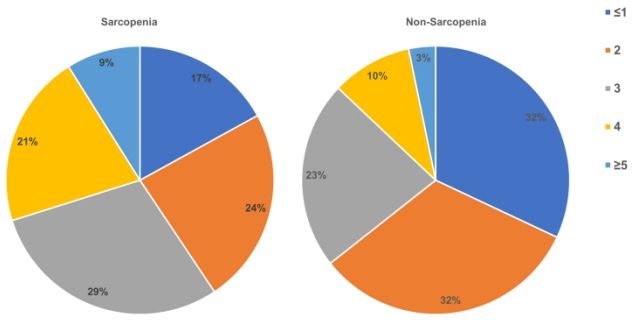

Proportion of ICVHMs in sarcopenia and non-sarcopenia.

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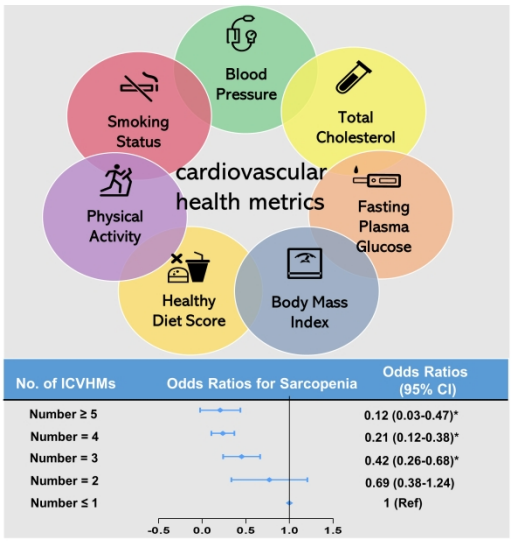

Association between number of ICVHMs and sarcopenia

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		
Male				
< 45	1[Ref]	0.46 (0.24-0.88)	0.022	0.725
45 - 59	1[Ref]	0.35 (0.12-1.06)9	0.069	
Female				
< 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
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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
Discussion			
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
Other information			
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.

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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 ≥ 20 years of age and excluded those who could not diagnose sarcopenia or insufficient data to calculate the CVH scores.

Primary and secondary outcome measures: The prevalence of sarcopenia as 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 ± 0.06 and 5.43 ± 0.05, respectively. After adjusting for related confounding factors, 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) and 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). Moreover, if the number of ideal CVH metrics was > 5, the odds of sarcopenia decreased by up to 85% (aOR: 0.15, 95% CI: 0.06-0.38, P < 0.001).

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

Keywords: cardiovascular health metrics, sarcopenia, NHANES

Strengths and limitations of this study

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

This study suggests a relationship between the CVH and the prevalence of non-cardiovascular disease, sarcopenia. The results of our study 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 sarcopenia.

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

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

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-

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

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

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

Methods

Patient and public involvement

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

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

DXA, appendicular skeletal muscle mass, and the definition of sarcopenia

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

Appendicular skeletal muscle mass was measured using DXA. The sarcopenia index was calculated as follows: sarcopenia index = total appendicular skeletal muscle mass (in kg)/BMI (kg/m^2).

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 National Institutes of Health (FNIH).

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 ≤ 50 were assigned to poor health, those with a score of 51-80 to intermediate health, and those with a score ≥ 81 to ideal health.

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

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

Intermediate	Former ≤ 12 months	202 (7.2)
Poor	Current smoking	1897 (52.8)
Body mass index, n (%)		
Ideal	< 25 kg/m^2	1025 (30.3)
Intermediate	25-29.9 kg/m^2	1080 (33.8)
Poor	≥ 30 kg/m^2	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 *, 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.
† CVH is defined from AHA in 2010. (5)
* AHA's healthy diet score includes five components: fruits and vegetables, whole grain, fish, sodium, and sugar-sweeten 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 from0 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; intermediate diet: 51-80; and poor diet: ≤ 50.

Although the AHA relies on fasting glucose to determine hyperglycemia, we use hemoglobin A1c (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 ≥ 6.5% as a proxy for fasting plasma glucose levels < 100 mg/dL, 100 to < 126 mg/dL, and ≥ 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 measured with enzymatic methods (https://www.cdc.gov/nchs/nhanes/index.htm). BMI was calculated as the weight in kilograms divided by the height in meters squared. The

mean blood pressure was estimated from up to three readings obtained under standard conditions during a single physical examination.

For each metric, participants received 0, 1, or 2 points, representing poor, intermediate, or ideal categories, respectively. Participants with 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 low number of people with an ideal CVH score in this sample, the intermediate and ideal CVH categories were combined.

Statistical analysis

We used the NHANES recommended weights to account for planned oversampling of specific groups. The continuous variables were expressed as the mean ± standard error, and the categorical variables were presented as counts (percentages). Baseline characteristics between the two CVH groups were compared using a t-test for continuous variables and a χ^2 test for categorical variables.

Multiple logistic regression was used to examine the independent influence of CVH on sarcopenia comparing poor CVH versus intermediate or ideal CVH after adjustments for potential confounders, such as age, sex, and race/ethnicity, educational level and alcohol. The odds ratio (OR) and 95% confidence interval (CI) were computed. We explored the relationship between CVH and sarcopenia in different subgroups (age, sex, race/ethnicity, education level and alcohol use). We also separately estimated the association between individual components of the CVH metrics and sarcopenia. When assessing the role of individual components, the age, sex, race/ethnicity, and education level were adjusted. Furthermore, we used multiple logistic regression analysis to assess the effect of a different number of ideal cardiovascular health metrics

(ICVHMs) on the incidence of sarcopenia. A two-sided *P*-value < 0.05 indicated significance for all analyses. All data analyses were performed using SAS Release 9.4 (SAS Institute) and Survey package in R software (version 4.0.4; R Foundation for Statistical Computing, Vienna, Austria).

Results

Baseline characteristics

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 ideal level for the remainder of CVH metrics were cigarette smoking (weighted proportion, 40.1%), diabetes (weighted, 75.8%), total cholesterol level (weighted, 49.8%), blood pressure (weighted, 45.2%), physical activity (weighted, 44.5%), and BMI (weighted, 30.3%) (**Table 1**).

This cohort study involved 3311 adults ≥ 20 years of age, comprising 1329 females (weighte, 42.4%) and 1982 males (weighted, 47.6%), with a weighted mean (SE) age of 40.0 ± 0.4 years. 1477 (weighted, 66.6%) were of non-Hispanic white ancestry, 753 (weighted, 15.7%) of Hispanic ancestry, and 618 (weighted, 9.6%) of non-Hispanic Black ancestry. The study population characteristics are 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 9.3 ± 0.1 and 5.4 ± 0.1, respectively. The differences of CVH metrics were significant for age, race/ethnicity, and education ($P < 0.001$). The frequency in the present sample of sarcopenia in participants with poor CVH metrics was 9.9%, more than two times as participants with intermediate or ideal CVH

metrics (3.6%). Moreover, we analyzed the characteristics of this study population by sarcopenic status. Sarcopenia was identified in 32.1% of 89 females based on the sarcopenia criteria and the Hispanic more like to develop sarcopenia (36.5%) compared with other races/ethnicities. Heavy use of alcohol did not show significant differences between both groups (P = 0.821). Furthermore, the patient with sarcopenia had poor education level, BMI risk, healthy diet score risk, blood pressure risk, fasting plasma glucose risk, and overall CVH metrics. And more detailed analyses are presented in **Table S1**.

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)	< 0.001
Non-Hispanic Black	618 (9.6)	232 (7.2)	386 (12.4)	
Non-Hispanic White	1477 (66.6)	760 (69.8)	717 (63.0)	
Other	463 (8.1)	238 (7.7)	225 (8.6)	
Heavy use of alcohol, n (%) *				
< 12	2558 (96.4)	1273 (97.4)	1285 (95.1)	0.062
≥ 12	103 (3.6)	40 (2.6)	63 (4.9)	
Education levels, n (%)				
< 12	1645 (44.9)	735 (41.8)	910 (48.3)	0.005
12	1135 (35.7)	543 (35.5)	592(36.0)	

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

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

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). For all of subgroups, there was no significant interaction (all *P* for interaction > 0.05).

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

Variable	No. (%)	Intermediate or Ideal CVH OR (95%CI) †	*P* value	Intermediate or Ideal CVH OR (95%CI) *	*P* value	*P* for interaction
Continuous						
CVH (per 1 score)	247/3311	0.75 (0.70-0.81)	<0.001	0.76 (0.70-0.83)	<0.001	-
Categories †						
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	-
Subgroup						
Age						
<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	
Sex						
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	
Race						
Hispanic	126/753	0.38 (0.23-0.63)	<0.001	0.42 (0.23-0.77)	0.007	0.695
Non-Hispanic Black	17/618	0.16 (0.04-0.73)	0.019	0.25 (0.07-0.88)	0.038	
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	
Education levels						
<12	158/1645	0.51 (0.28-0.91)	0.024	0.55 (0.27-1.11)	0.101	0.093
12	70/1135	0.35 (0.14-0.88)	0.026	0.31 (0.11-0.93)	0.041	
>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.

† Unadjusted model.

* 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 ≥ 3 ICVHMs (**Figure 2**). Logistic regression of the ICVHM number and the odds of sarcopenia revealed that the higher the number of ICVHMs, the lower the odds of sarcopenia. When participants had 3 ideal CVH metrics, the odds 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 ≥ 5, the odds 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 odds of sarcopenia odds 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 odds 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 were observed between increasing levels of CVH components for BMI, 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**).

213

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
Smoking status				
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	
Body mass index				
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	
Healthy diet score				
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	
Total cholesterol				
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	
Fasting plasma glucose				
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	

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 showed a significantly 60% decreased adjusted risk of sarcopenia in subjects with better CVH metrics. For each unit increase in the metrics of CVH, the risk of CVDs decreased by 24%. Furthermore, higher intermediate or ideal CVH metrics were associated with a lower prevalence of sarcopenia.

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

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

Second, we further observed the effects of CVH metrics on sarcopenia in different subgroups. We have reported that CVH influences the incidence of sarcopenia not only in the elderly population, (14) but in the younger population. In addition, we demonstrated similar results in the ethnicity subgroups. Surprisingly, it appeared that poor CVH metrics in females did not affect the prevalence of sarcopenia. However, we found that the effect of CVH metrics was even stronger in young and middle-aged females than in males. Sex differences in antioxidant status may

have contributed to this phenomenon. Earlier studies demonstrated significant sex-dependent differences in GPx (selenoproteins, such as GPx-1 and GPx-3) activity, (18) while postmenopausal females have relatively high levels of systemic oxidative stress. (19) This finding suggests that younger female may have higher levels of antioxidant enzymes and poor CVH metrics may significantly disrupt the antioxidant levels, and thus make the individual more susceptible to sarcopenia.

Third, we attempted to determine the effect of each indicator in CVH alone on sarcopenia in this study. Our study showed that reduced fasting plasma glucose levels were associated with a decreased risk of sarcopenia. This was consistent with the results of previous studies. (20) 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 blood pressure was the second significant feature associated with sarcopenia. Han P et al. (14) also found that hypertension is an independent risk factor for sarcopenia. Although the mechanism underlying sarcopenia and hypertension is currently unknown, recent studies have concluded that inflammatory factors during aging could impair blood flow by damaging the microvascular endothelium, (22) which exerted a detrimental effect on the body of the elderly. Additional studies are needed to elucidate the causal relationship between hypertension and sarcopenia. Healthy eating is significantly associated with sarcopenia. The Papaioannou study (23) highlighted the beneficial link between healthy eating and sarcopenia risk. There are several possible mechanisms to explain the beneficial effects of a healthy diet on skeletal muscle. First, a healthy diet rich in fruits and vegetables prevents metabolic acidosis and reduces protein hydrolysis and amino acid catabolism, thus reducing the risk of sarcopenia. (24) In addition, unfavorable dietary patterns, including foods rich in saturated fats, may be detrimental to the maintenance of muscle

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 sarcopenia and malnutrition and is associated with higher mortality in the older population. (27) Conversely, obese patients may have a survival benefit. (28) However, our study still found that being overweight or obese can significantly increase the risk of sarcopenia. The poor prediction of physical activity in the present study was unexpected, in contrast to previous studies (29) that suggested only ideal physical activity does 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 middle-aged adults. Physical activity may be crucial for the occurrence of sarcopenia in the elderly population.

Our study has several limitations. First and foremost, cigarette smoking, physical activity, and diet were self-reported, and subjected to misclassification and recall bias, which can lead to an over- or under-estimated association between CVH and sarcopenia. Second, as noted above, for practical reasons, we were not fully compliant with all of the AHA 2020 health indicators. Moreover, our study was cross-sectional, so the association between CVH and sarcopenia cannot be interpreted as a direct cause-and-effect relationship. Finally, 84 percent of initial 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 is available in the future.

Conclusion

In conclusion, our findings suggested a relationship between CVH indicators and the prevalence of sarcopenia among US adults. Our analysis

confirms that CVH extends beyond protection against cardiovascular disease. More research is needed to clarify the association between CVH 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 supported by efforts to reduce the prevalence of sarcopenia.

Contributorship statement

The authors' contributions were as follows; WHC: participated in formulating the research question, design of analyses, interpretation of the data, drafting the manuscript, revising the manuscript, and the approval of the final version; SSS: participated in the design of analyses, data analysis, revising the manuscript, and approval of the final version; YZJ: drafting the manuscript, revising the manuscript, and the approval of the final version; YL: interpretation of the data and the approval of the final version; KHC: participated in formulating the research question, design of analyses, revising the manuscript, and the approval of the final version; RCH: participated in formulating the research question, design of analyses, data analysis, interpretation of the data, and the approval of the final version; KH: participated in formulating the research question, design of analyses, data analysis, interpretation of the data, and the approval of the final version; and all authors: read and approved the final version of the manuscript and are responsible for all aspects of the manuscript.

Competing interests

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

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Data sharing statement

None

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Figure Legend

Title to Figure 1

Flowchart.

Title to Figure 2

Proportion of ICVHMs in sarcopenia and non-sarcopenia.

Title to Figure 3

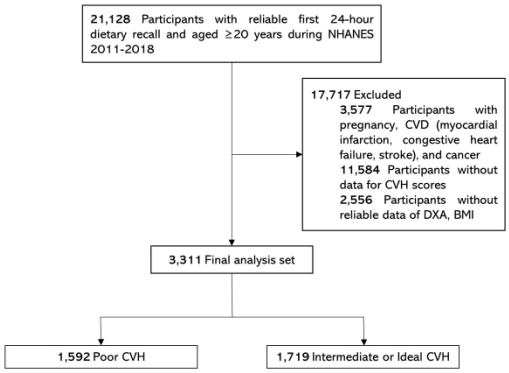
Association between number of ICVHMs and sarcopenia.

Legend to Figure 3

Abbreviation: ICVHMs, Ideal cardiovascular health metrics.

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

* $P < 0.05$.



Flowchart.

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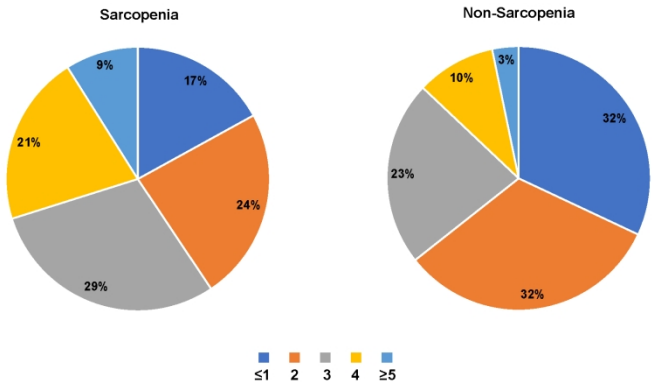

Proportion of ICVHMs in sarcopenia and non-sarcopenia.

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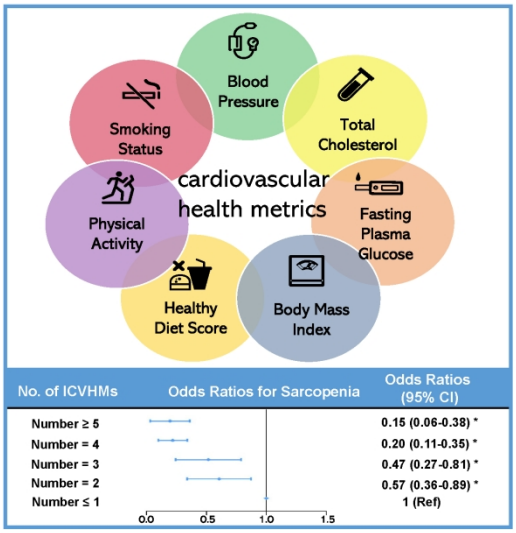

Association between number of ICVHMs and sarcopenia.

338x190mm (200 x 200 DPI)

Table S1 Baseline characteristics of the study population by sarcopenic.

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

Ideal	1435 (48.5)	105 (42.7)	
Intermediate	207 (7.5)	11 (5.5)	0.227
Poor	1422 (44.0)	131 (51.8)	
Healthy diet score risk, n (%)			
Ideal	41 (1.8)	1 (0.0)	
Intermediate	1119 (38.3)	80 (31.0)	0.010
Poor	1904 (59.8)	166 (69.0)	
Total cholesterol risk, n (%)			
Ideal	1651 (50.5)	100 (39.6)	
Intermediate	845 (29.9)	80 (35.8)	0.096
Poor	568 (19.6)	67 (24.6)	
Blood pressure risk, n (%)			
Ideal	1387 (46.6)	72 (25.7)	
Intermediate	1016 (33.3)	92 (37.6)	< 0.001
Poor	661 (20.1)	83 (36.8)	
Fasting plasma glucose risk, n (%)			
Ideal	2167 (77.3)	115 (53.0)	
Intermediate	628 (15.6)	85 (32.4)	< 0.001
Poor	269 (7.1)	47 (14.6)	
Scores of seven healthy metrics, mean (SE)	7.6 (0.1)	5.9 (0.2)	< 0.001
Overall CVH metrics, n (%)			
Poor	1539 (45.5)	180 (71.2)	< 0.001
Intermediate or Ideal	1525 (54.5)	67 (28.8)	

Abbreviations: CVH, cardiovascular health.

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

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		
Male				
< 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	
Female				
< 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
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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
Discussion			
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
Other information			
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.

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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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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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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 ≥ 20 years of age and excluded those who could not diagnose sarcopenia or insufficient data to calculate the CVH scores.

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

Results: This cohort study involving 9,326 adults ≥ 20 years comprised 4,733 females (50.0%). The number of intermediate or ideal and poor CVH participants was 5,654 and 3,672 with mean CVH score of 9.70 ± 0.03 and 5.66 ± 0.04, respectively. After adjusting for related confounding factors, intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (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 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 was > 5, the odds of sarcopenia decreased by up to 84% (aOR: 0.16, 95% CI: 0.08-0.30).

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

Keywords: cardiovascular health metrics, sarcopenia, NHANES

Strengths and limitations of this study

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

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

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

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

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

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

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

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

Methods

Patient and public involvement

NHANES is a nationally representative health survey designed and administered by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC) and was approved by the NCHS Research Ethics Review Board (protocols

Numbers: NHANES Protocol #2011-17 and NHANES Protocol #2018-01). The NHANES was designed to represent the civilian non-institutionalized United States population using a complex multistage probability sampling methodology. We conducted a retrospective analysis of a cohort of US population of the NHANES from 2011 to 2018. Written informed consent was acquired from each NHANES participant. The NHANES includes extensive demographic data, physical examinations, laboratory tests, health-related questionnaires and lists of prescription medications, which were measured at the start of the study. Further details on the data collection procedure and analytical guidelines are publicly available on the NHANES website. (15) As shown in **Figure S1**, this study included participants with reliable first 24-h dietary recall and ≥ 20 years of age during NHANES 2011-2018 (n = 21,128). Of these participants, 11,802 were excluded based on the following: (i) no reliable dual-energy X-ray absorptiometry (DXA) and body mass index (BMI) data; and (ii) insufficient data to calculate the CVH scores. Thus, 9,326 participants were enrolled in the present study.

DXA, appendicular skeletal muscle mass, and the definition of sarcopenia

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

Appendicular skeletal muscle mass was measured using DXA. The sarcopenia index was calculated as follows: sarcopenia index = total appendicular skeletal muscle mass (in kg)/BMI (kg/m^2).

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 National Institutes of Health (FNIH).

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. (5)

AHA definitions of CVH for each metric		Total sample (n=9,326)
Smoking status, n (%)		
Ideal	Never or quit >12 mo	7,003 (75.2)
Intermediate	Former ≤12 mo	216 (2.9)
Poor	Yes	2,107 (22.0)
Body mass index, n (%)		
Ideal	< 25 kg/m^2	2,890 (31.1)
Intermediate	25-29.9 kg/m^2	2,937 (32.6)
Poor	≥ 30 kg/m^2	3,499 (36.3)
Physical activity, n (%)		
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)
Healthy diet score *, n (%)		
Ideal	4-5 components	201 (2.2)
Intermediate	2-3 components	4,046 (44.3)
Poor	0-1 components	5,079 (53.5)
Total cholesterol, n (%)		
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)
Blood pressure, n (%)		
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-sweeten 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 from0 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; intermediate diet: 51-80; and poor diet: ≤ 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 ≥ 6.5% as a proxy for fasting plasma glucose levels < 100 mg/dL, 100 to < 126 mg/dL, and ≥ 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

measured with enzymatic methods (https://www.cdc.gov/nchs/nhanes/index.htm). BMI was calculated as the weight in kilograms divided by the height in meters squared. The mean blood pressure was estimated from up to three readings obtained under standard conditions during a single physical examination.

For each metric, participants received 0, 1, or 2 points, representing poor, intermediate, or ideal categories, respectively. Participants with 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 low number of people with an ideal CVH score in this sample, the intermediate and ideal CVH categories were combined.

Statistical analysis

We used the NHANES recommended weights to account for planned oversampling of specific groups. The continuous variables were expressed as the mean ± standard error, and the categorical variables were presented as counts (percentages). Baseline characteristics between the two CVH groups were compared using a t-test for continuous variables and a χ^2 test for categorical variables.

Multiple logistic regression was used to examine the independent influence of CVH on sarcopenia comparing poor CVH versus intermediate or ideal CVH after adjustments for potential confounders, such as age, sex, and race/ethnicity, educational level, alcohol,

congestive heart failure, coronary heart disease, angina and cancer. The odds ratio (OR) and 95% confidence interval (CI) were computed. We explored the relationship between CVH and sarcopenia in different subgroups (age, sex, race/ethnicity and education level). We also separately estimated the association between individual components of the CVH metrics and sarcopenia. When assessing the role of individual components, the age, sex, and race/ethnicity, educational level, alcohol, congestive heart failure, coronary heart disease, angina and cancer were adjusted. Furthermore, we used multiple logistic regression analysis to assess the effect of a different number of ideal cardiovascular health metrics (ICVHMs) on the incidence of sarcopenia. A two-sided *P*-value < 0.05 indicated significance for all analyses. All data analyses were performed using SAS Release 9.4 (SAS Institute) and Survey package in R software (version 4.0.4; R Foundation for Statistical Computing, Vienna, Austria).

Results

Baseline characteristics

This study shown that only 2.2% of the participants met the ideal diet criteria. The frequency in the present sample of participants meeting the ideal level for the remainder of CVH metrics were cigarette smoking (weighted, 75.2%), HbA1c (weighted, 75.2%), total cholesterol level (weighted, 54.1%), blood pressure (weighted, 49.1%), physical activity (weighted, 41.9%), and BMI (weighted, 31.1%) (**Table 1**).

This cohort study involved 9,326 adults ≥ 20 years of age, comprising 4,733 females (weighted, 50.0%) and 4,593 males (weighted, 50.0%), with a weighted mean (SE) age of 39.3 ± 0.3 years. 3,323 (weighted, 60.3%) were of non-Hispanic white ancestry, 967 (weighted, 7.3%) of Hispanic ancestry, and 1,955 (weighted, 11.3%) of non-Hispanic Black ancestry. The study population characteristics are listed in **Table 2** by CVH metrics. The number of intermediate or ideal and CVH participants was 5,654 and 3,672, with mean CVH metrics of 9.7 ± 0.0 and 5.7 ± 0.0, respectively. The differences of CVH metrics were significant for age, race/ethnicity, and education ($P < 0.001$). The frequency in the present sample of sarcopenia in participants with poor CVH metrics was 12.3%, nearly three-fold as participants with intermediate or ideal CVH metrics (4.8%). Moreover, we analyzed the characteristics of this study population by sarcopenic status. Sarcopenia was identified in 45.9% of 403 females based on the sarcopenia criteria and the non-Hispanic white ancestry more like to develop sarcopenia (47.5%) compared with other races/ethnicities. Furthermore, the patient with sarcopenia had poor education level, BMI risk, healthy diet score risk, blood pressure risk, HbA1c risk, and overall CVH metrics. And more detailed analyses are presented in **Table S1**.

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

Race/ethnicity, n (%)				
Mexican American	1,406 (11.1)	846 (11.4)	560(10.5)	< 0.001
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)	
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)	
Heavy use of alcohol, n (%) *				
< 12	6,636 (97.8)	4,111 (98.5)	2,525 (96.6)	0.173
≥ 12	156 (2.2)	75 (1.5)	81 (3.4)	
Education levels, n (%)				
< 12	3,675 (34.6)	1,989 (31.0)	1,686 (40.9)	< 0.001
12	3,092 (34.0)	1,863 (33.6)	1,299(34.6)	
> 12	2,557 (31.4)	1,800 (35.4)	757 (24.5)	
Scores of CVH metrics, mean (SE)	8.24 (0.04)	9.70 (0.03)	5.66 (0.04)	< 0.001
No	8,519 (92.5)	5,326 (95.2)	3,193 (87.7)	
Congestive heart failure	97 (1.0)	23 (0.2)	74 (1.8)	< 0.001
Coronary heart disease	92 (1.0)	17 (0.2)	75 (2.2)	< 0.001
Angina	94 (1.0)	30 (0.4)	64 (2.2)	< 0.001
Cancer	349 (5.0)	158 (3.9)	191 (6.8)	< 0.001
Sarcopenia, n (%)				
Yes	807 (7.5)	328 (4.8)	479 (12.3)	< 0.001
No	8,519 (92.5)	5,326 (95.2)	3,193 (87.7)	

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 [OR]: 0.36 0.29-0.44, $P < 0.001$; **Table 3**). After adjusting for age, sex, race/ethnicity, education level, alcohol use, congestive heart failure, coronary heart disease, angina and cancer, intermediate or ideal CVH was associated with an odds reduction of sarcopenia than poor CVH (adjusted 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 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 were performed for age, sex, race/ethnicity, and education level. And the association between intermediate or ideal CVH and sarcopenia was significant in different subgroups. Notably, the age group also showed stronger association in the subgroup aged < 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 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, $P = 0.038$; 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 interaction > 0.05), expect of education levels (P for interaction= 0.014).

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

Variable	No. (%)	Intermediate or Ideal CVH OR (95%CI) †	*P* value	Intermediate or Ideal CVH OR (95%CI) *	*P* value	*P* for interaction
Continuous						
CVH (per 1 score)	807/9,326	0.77 (0.74-0.79)	<0.001	0.75 (0.71-0.79)	<0.001	-
Categories †						
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	-
Subgroup						
Age						
<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	
Sex						
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	
Race						
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	
Education levels						
<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	

Abbreviations: CVH, cardiovascular health; OR, odds ratio.
† Unadjusted model.
* Analyses were adjusted for age, sex, race/ethnicity, education level, alcohol use, congestive heart failure, coronary heart disease, angina and cancer.
Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.

Association between number of ICVHMs and sarcopenia

21% of participants with sarcopenia had only 1 ICVHM and 5% had 5 ideal ICVHMs. In participants without sarcopenia, up to 70% had ≥ 3 ICVHMs (**Figure S2**). Logistic regression of the ICVHM number and the odds of sarcopenia revealed that the higher the number of ICVHMs, the lower the odds of sarcopenia. When participants had 3 ideal CVH metrics, the odds of sarcopenia decreased 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 ≥ 5, the odds of sarcopenia decreased by up to 84% (aOR: 0.16, 95% CI: 0.08-0.30; **Figure 1**).

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 odds of sarcopenia odds than those with ideal CVH in all CVH metric subgroups except for the subgroup with cigarette smoking status, total cholesterol, and physical activity. Especially in the BMI and healthy diet score subgroups, the odds of sarcopenia 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 decreasing odd of sarcopenia trends were observed between increasing levels of CVH components for BMI, healthy diet score, HbA1c and blood pressure (all *P for trend* < 0.05; **Table 4**).

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

Variable	OR *	95%CI	*P* value	*P* for trend
Smoking status				
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	
Body mass index				
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	
Healthy diet score				

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	
Total cholesterol				
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	
Glycated hemoglobin A1c				
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	
Physical activity				
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	
Blood pressure				
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	

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

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

Discussion

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

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

Our study yielded several interesting findings. First, the CVH metrics were not only associated with CVDs, but also non-CVDs, including sarcopenia. This result agreed with Han et al., (16) who also reported that sarcopenia was independently associated with cardiovascular risk factors, including diabetes and hypertension. And these risk factors were shown to be associated with the prevalence of sarcopenia defined by the recommended algorithm of the Asian Working Group in the Chinese elderly. (14) However, these results may only be applicable in patient with high-risk cardiovascular risk factors. In order to explore the association between sarcopenia and the common individual with average or only slightly unfavorable levels of risk factors, we chose CVH and elaborated on the detail and found that higher intermediate or ideal CVH metrics were associated with a lower prevalence of sarcopenia, as defined by the recommended algorithm of the FNIH in American adults. This finding suggests that the level of CVH influences the incidence of sarcopenia and emphasizes the greater importance of CVH for health care and medical conditions. A previous study showed that the presence of more desirable CVH indicators was associated with a significant reduction in CVD morbidity and mortality (17). Our study broadens the application value of the CVH metrics; specifically, the higher the number of intermediate or ideal CVH metrics, the lower the incidence of sarcopenia. It showed that only a small percentage of American adults met the ideal criteria for 6

or 7 ideal health metrics. This result is disappointing, but perhaps not surprising. Furthermore, this result challenges clinical and public health professionals to keep steering the health metrics in the desired direction. In the meantime, additional research is warranted in the future to explore CVH and non-cardiovascular fields to increase public awareness of CVH and promote achievement of AHA 2030 goals.

Second, we further observed the effects of CVH metrics on sarcopenia in different subgroups. We have reported that CVH influences the incidence of sarcopenia not only in the elderly population, (14) but in the younger population. In addition, we demonstrated similar results in the sex and ethnicity subgroups. Surprisingly, it appeared that the ideal CVH metrics affect different levels of participant with different levels of education. Recent study shown that low education compared to high education was associated with lower odds of having ideal CVH (18). However, it appears that participants with higher levels of education are able to benefit more from the ideal CVH. At the same time, participants with low education levels also reduced the prevalence of sarcopenia 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 levels, but also need to further increase the attainment rate of ideal CVH for participation with high education levels to achieve further benefits.

Third, we attempted to determine the effect of each indicator in CVH alone on sarcopenia in this study. Our study showed that reduced HbA1c levels were associated with a decreased risk of sarcopenia. This was consistent with the results of previous studies.

(19) 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 blood pressure was the second significant feature associated with sarcopenia. Han P et al. (14) also found that hypertension is an independent risk factor for sarcopenia. Although the mechanism underlying sarcopenia and hypertension is currently unknown, recent studies have concluded that inflammatory factors during aging could impair blood flow by damaging the microvascular endothelium, (21) which exerted a detrimental effect on the body of the elderly. Additional studies are needed to elucidate the causal relationship between hypertension and sarcopenia. Healthy eating is significantly associated with sarcopenia. The Papaioannou study (22) highlighted the beneficial link between healthy eating and sarcopenia risk. There are several possible mechanisms to explain the beneficial effects of a healthy diet on skeletal muscle. First, a healthy diet rich in fruits and vegetables prevents metabolic acidosis and reduces protein hydrolysis and amino acid catabolism, thus reducing the risk of sarcopenia. (23) In addition, unfavorable dietary patterns, including foods rich in saturated fats, may be detrimental to the maintenance of muscle 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 sarcopenia and malnutrition and is associated with higher mortality in the older population. (26) Conversely, obese patients may have a survival benefit. (27) However, our study still found that being overweight or obese can significantly increase the risk of sarcopenia. The poor prediction of physical activity in the present study was unexpected, in contrast to previous studies (28) that suggested only ideal physical activity does 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 middle-aged adults. Physical activity may be crucial for the occurrence of sarcopenia in the elderly population.

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

Conclusion

In conclusion, our findings suggested a relationship between CVH indicators and the prevalence of sarcopenia among US adults. Our analysis confirms that CVH extends beyond protection against cardiovascular disease. More research is needed to clarify the association between CVH 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 supported by efforts to reduce the prevalence of sarcopenia.

Contributorship

The authors' contributions were as follows; WHC: participated in formulating the research question, design of analyses, interpretation of the data, drafting the manuscript, revising the manuscript, and the approval of the final version; SSS: participated in the design of analyses, data analysis, revising the manuscript, and approval of the final version; YZJ: drafting the manuscript, revising the manuscript, and the approval of the final version; YL: interpretation of the data and the approval of the final version; KHC: participated in formulating the research question, design of analyses, revising the manuscript, and the approval of the final version; RCH: participated in formulating the research question, design of analyses, data analysis, interpretation of the data, and the approval of the final version; KH: participated in formulating the research question, design of analyses, data analysis, interpretation of the data, and the approval of the final version; and all authors: read and approved the final version of the manuscript and are responsible for all aspects of the manuscript.

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Competing interests

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

Ethics approval

NHANES was approved by the NCHS Research Ethics Review Board (protocols Numbers: NHANES Protocol #2011-17 and NHANES Protocol #2018-01).

Data sharing statement

None

Acknowledgements

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Figure Legend

Title to Figure 1

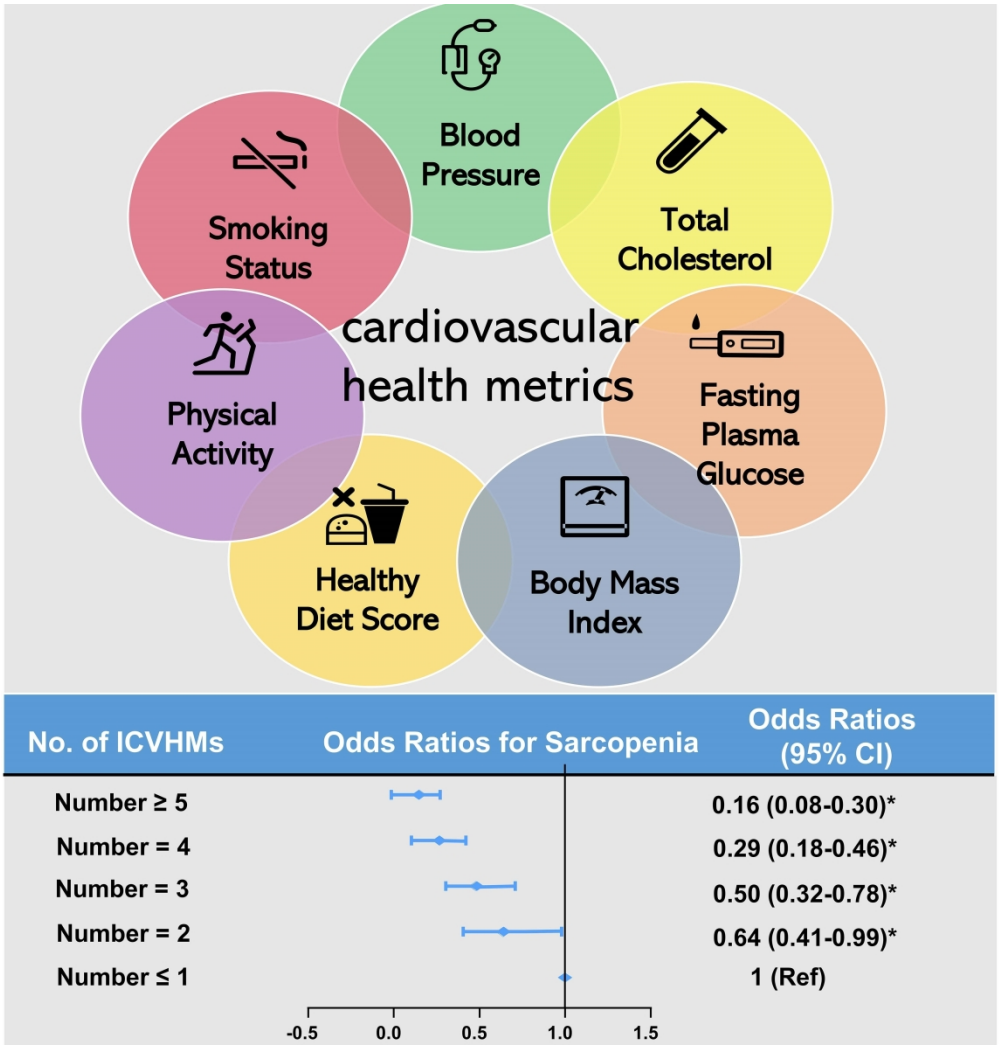
Association between number of ICVHMs and sarcopenia.

Legend to Figure 1

Abbreviation: ICVHMs, Ideal cardiovascular health metrics.

Model: Adjusted by age, sex, and race/ethnicity, educational level, alcohol use, congestive heart failure, coronary heart disease, angina and cancer.

* $P < 0.05$.



Association between number of ICVHMs and sarcopenia.

345x358mm (300 x 300 DPI)

Table S1 Baseline characteristics of the study population by sarcopenic.

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

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

Abbreviations: CVH, cardiovascular health.
Poor CVH: CVH metrics scores 0-7; Intermediate or Ideal CVH: CVH metrics scores 8-14.

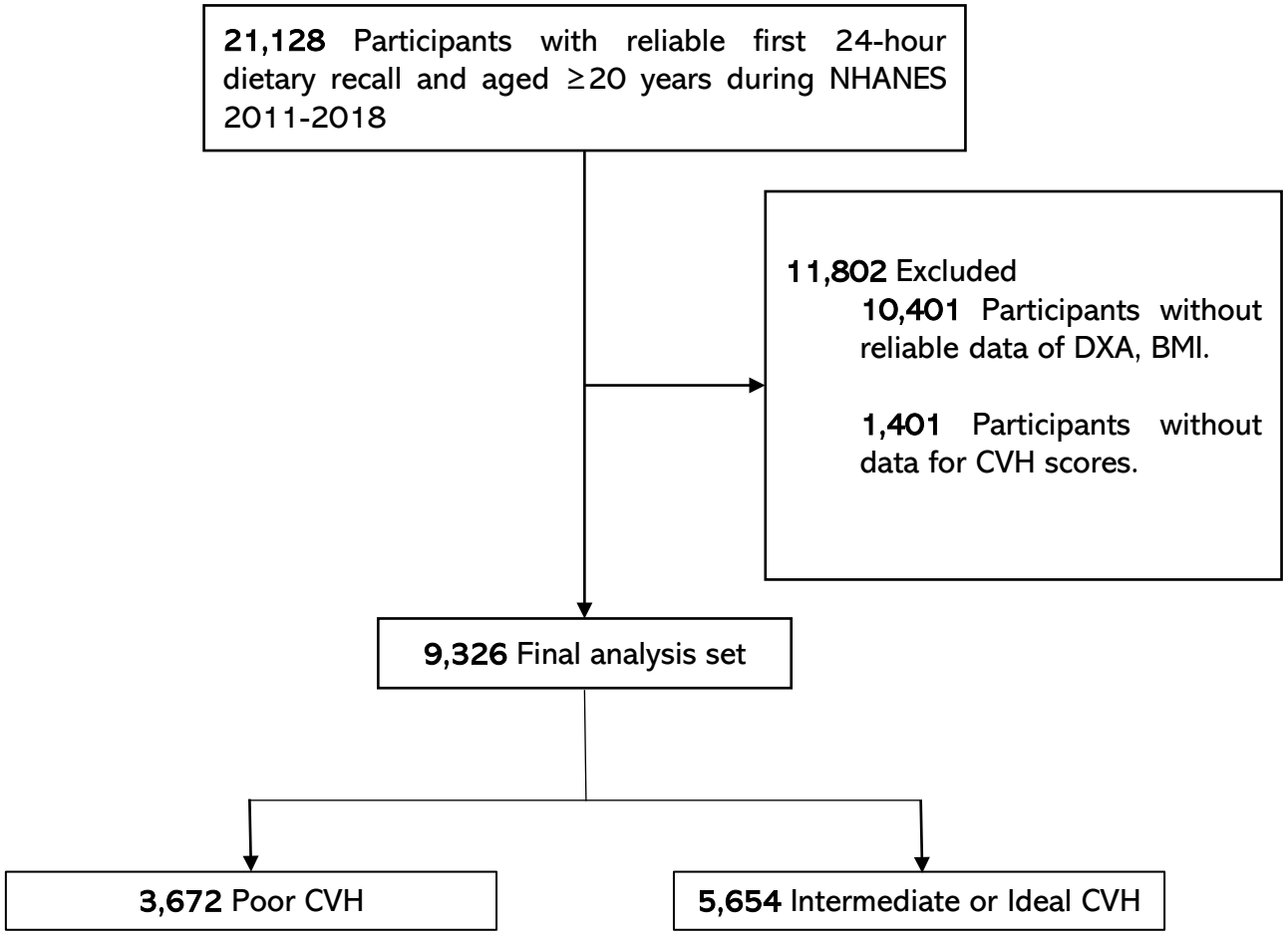


Figure S1. Flowchart.

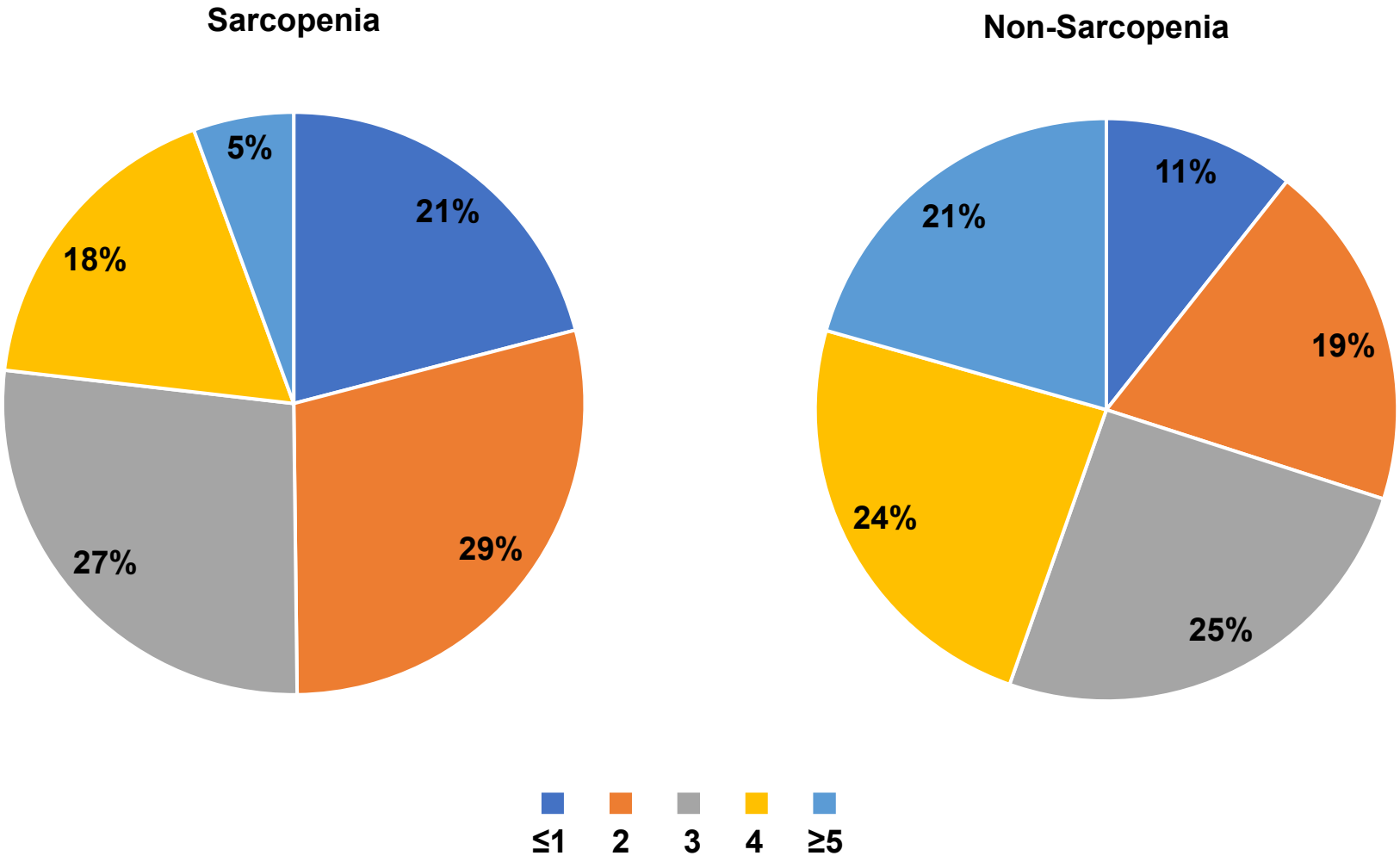


Figure S2. Proportion of ICVHMs in sarcopenia and non-sarcopenia.

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

	Item No	Recommendation	Page No
Title and abstract	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
Introduction			
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
Methods			
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
Results			
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
Discussion			
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
Other information			
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.