ORIGINAL ARTICLE

Journal of Cachexia, Sarcopenia and Muscle 2015
Published online in Wiley Online Library (wileyonlinelibrary.com) **DOI:** 10.1002/jcsm.12048

SARC-F: a symptom score to predict persons with sarcopenia at risk for poor functional outcomes

Theodore K. Malmstrom[1,2*], Douglas K. Miller[3], Eleanor M. Simonsick[4], Luigi Ferrucci[4] & John E. Morley[2]

[1]*Department of Neurology & Psychiatry, Saint Louis University School of Medicine, St. Louis, MO 63104, USA;* [2]*Division of Geriatric Medicine, Department of Internal Medicine, Saint Louis University School of Medicine, St. Louis, MO 63104, USA;* [3]*Regenstrief Institute, Inc. and Center for Aging Research, Indiana University School of Medicine, Indianapolis, IN 46202, USA;* [4]*National Institute on Aging, Translational Gerontology Branch, Biomedical Research Center, Baltimore, MD 21224, USA*

Background A brief, inexpensive screening test for sarcopenia would be helpful for clinicians and their patients. To screen for persons with sarcopenia, we developed a simple five-item questionnaire (SARC-F) based on cardinal features or consequences of sarcopenia.

Methods We investigated the utility of SARC-F in the African American Health (AAH) study, Baltimore Longitudinal Study of Aging (BLSA), and National Health and Nutrition Examination Survey (NHANES). Internal consistency reliability for SARC-F was determined using Cronbach's alpha. We evaluated SARC-F factorial validity using principal components analysis and criterion validity by examining its association with exam-based indicators of sarcopenia. Construct validity was examined using cross-sectional and longitudinal differences among those with high ($\geq$4) vs. low ($<$4) SARC-F scores for mortality and health outcomes.

Results SARC-F exhibited good internal consistency reliability and factorial, criterion, and construct validity. AAH participants with SARC-F scores $\geq$ 4 had more Instrumental Activity of Daily Living (IADL) deficits, slower chair stand times, lower grip strength, lower short physical performance battery scores, and a higher likelihood of recent hospitalization and of having a gait speed of $<$0.8 m/s. SARC-F scores $\geq$ 4 in AAH also were associated with 6 year IADL deficits, slower chair stand times, lower short physical performance battery scores, having a gait speed of $<$0.8 m/s, being hospitalized recently, and mortality. SARC-F scores $\geq$ 4 in the BLSA cohort were associated with having more IADL deficits and lower grip strength (both hands) in cross-sectional comparisons and with IADL deficits, lower grip strength (both hands), and mortality at follow-up. NHANES participants with SARC-F scores $\geq$ 4 had slower 20 ft walk times, had lower peak force knee extensor strength, and were more likely to have been hospitalized recently in cross-sectional analyses.

Conclusions The SARC-F proved internally consistent and valid for detecting persons at risk for adverse outcomes from sarcopenia in AAH, BLSA, and NHANES.

Keywords Sarcopenia; Screening; Mobility; Function

Received: 12 September 2014; Revised: 7 April 2015; Accepted: 23 April 2015
**Correspondence to: Theodore K. Malmstrom, Department of Neurology & Psychiatry, School of Medicine, Saint Louis University, 1438 South Grand Boulevard, St. Louis, MO 63104, USA, Tel: 314-977-4814, Fax: 314-977-4879, Email: malmsttk@slu.edu*

Introduction

Sarcopenia was originally defined as age-related loss of muscle mass.[1,2] Recently, a number of definitions of sarcopenia have been suggested that include a functional measure (e.g. limited mobility) together with appendicular lean mass corrected for height.[3–5] Others have argued that muscle strength or power is a more appropriate addition to loss of muscle mass or that a new term dynapenia (poverty of muscle strength/power) should be used separately from sarcopenia, which then would be reserved solely for poverty of muscle mass.[6–8] Regardless of definitional refinements, sarcopenia measured in several different ways has been associated with multiple adverse outcomes.[3–5] No easily applied sarcopenia measure currently exists for use in usual clinical settings.

In the osteoporosis field, it has been demonstrated that a simple questionnaire (FRAX) can predict persons with elevated risk of osteoporotic fracture without the requirement of measuring bone mineral density (BMD).[9,10] As loss of muscle mass, unlike loss of bone, has a clear clinical symptom, that is, weakness, it should be possible to create a simple symptom score that will predict both sarcopenia and poor outcomes in persons with sarcopenia.

Our group has been conducting a panel study of community-dwelling, late middle-aged African Americans who were 49–65 years of age at cohort initiation in 2000–01, have high levels of disability,[11,12] and are known collectively as the African American Health (AAH) cohort. Previously, we have shown in this cohort that the increase in disability over 9 years can be predicted in those with limited mobility and low lean mass,[13] but this measure requires in-person and laboratory assessments. The Baltimore Longitudinal Study of Aging (BLSA) and National Health and Nutrition Examination Survey (NHANES) cohorts also include data that can be utilized to examine sarcopenia. In this study, we examine the validity of a simple clinical symptom index (SARC-F)[14] to screen for sarcopenia/dynapenia and to identify those at risk for sarcopenia-related adverse outcomes in AAH, BLSA, and NHANES.

Materials and methods

Study sample

The AAH project sampling and recruitment procedures have been described elsewhere.[12] In brief, AAH is a population-based longitudinal study of 998 African Americans from St. Louis, MO. Recruitment was performed using multistage probability sampling methodology designed to select approximately equal numbers of participants from two geographic strata, an inner-city area and near suburban neighbourhoods northwest of the city. AAH eligibility criteria included living independently (i.e. not institutionalized), self-reported black or African American race, birth year between 1936 and 1950, and a Mini-mental State Examination score of 16 or greater (98% ≥ 20). Recruitment proportion (participants/enumerated eligible persons) in 2000–01 was 76%. AAH Wave 1 (baseline) in-home interviews included $n = 998$ participants evaluated in 2000–01. Follow-up in-home interviews were done at in 2003–04 (Wave 4; $n = 853$) and 2010–11 (Wave 10; $n = 582$). The analytic sample for this report includes $n = 853$ Wave 4 respondents and outcomes at their 6 year follow-up (Wave 10). The institutional review board at Saint Louis University approved this project.

The BLSA was started in 1958 and is an ongoing longitudinal study of normal human aging.[15] BLSA participation is limited to adults who at the time of enrollment screening do not have major diseases, cognitive dysfunction, or functional impairment but once enrolled are followed for life. BLSA participants complete comprehensive health testing on a repeated cycle (1–4 years). The analytic sample for this study includes $n = 1053$ BLSA participants evaluated between April 2003 and December 2012 who were ages 60 and above and had valid data on the five items needed to construct the SARC-F and outcomes at follow-up (27.07 ± 11.7 months).

The NHANES 1999–2006 is an annual cross-sectional, nationally representative survey of approximately 5000 non-institutionalized individuals in the United States.[16] NHANES data are publically released in 2 year cycles. The primary objective of NHANES is to collect a comprehensive data set that can be utilized to assess the health and nutritional status of the national population of children and adults. NHANES data for 1999–2002 include $n = 21\,004$ participants with a median age of 19 (interquartile range 10–48) and 51.4% women. The analytic sample for this study includes $n = 3288$ NHANES 1999–2002 participants who were ages 60–85 with valid data on the five items needed to construct the SARC-F.

SARC-F questionnaire (0–10 points)

SARC-F includes five components: strength, assistance walking, rise from a chair, climb stairs, and falls. SARC-F items were selected to reflect health status changes associated with the consequences of sarcopenia.[3,4] SARC-F scale scores range from 0 to 10 (i.e. 0–2 points for each component; 0 = *best* to 10 = *worst*) and were dichotomized to represent symptomatic (4+) vs. healthy (0–3) status. The SARC-F scale was constructed using the same questions in AAH and BLSA. Strength was measured by asking respondents how much difficulty they had lifting or carrying 10 lbs. (0 = *no difficulty*, 1 = *some*, and 2 = *a lot or unable to do*). Assistance walking was assessed by asking participants how much difficulty they had walking across a room and whether they use aids or need help to do this (0 = *no difficulty*, 1 = *some difficulty*, and 2 = *a lot of difficulty, use aids, or unable to do without personal help*). Rise from a chair was measured by asking respondents how much difficulty they had transferring from a chair or bed and whether they used aids or needed help to do this (0 = *no difficulty*, 1 = *some difficulty*, and 2 = *a lot of difficulty, use aids, or unable to do without help*). Climb stairs was measured by asking respondents how much difficulty they had climbing a flight of 10 steps (0 = *no difficulty*, 1 = *some*, and 2 = *a lot or unable to do*). Falls was scored a 2 for respondents who reported falling four or more times in the past year, 1 for respondents who reported falling 1–3 times in the past year, and 0 for those reporting no falls in the past year. SARC-F construction in NHANES used the same strength and climb stairs items as in AAH and BLSA. There were minor wording differences in the NHANES items for assistance walking (assessed by asking difficulty walking between rooms on the same floor) and rise from

a chair (assessed by asking difficulty standing up from armless chair). NHANES did not ask participants to report the specific number of falls in the past year but did ask about difficulty with balance or falling in past year. The NHANES SARC-F falls was scored a 2 for respondents who reported falling problems in the past year, 1 for respondents who reported only balance problems in the past year, and 0 for those reporting no falling or balance problems in the past year.

Criterion validation measures

We examined the associations of SARC-F with muscle (lean mass per cent and total lean mass) and the short portable sarcopenia measure (SPSM) in the AAH cohort. The portable Tanita Ultimate Scale Model 2001 (Tanita Corporation of America, Arlington Heights, IL) bioelectrical impedance program was used to measure lean mass per cent (1 minus body fat per cent) and total lean mass [(1 minus body fat per cent) × body weight in lbs]. The SPSM scale is a brief field measure for sarcopenia that includes three components: upper body relative strength (grip strength/height), lower body power and strength (timed chair stands), and lean mass [(1 minus body fat per cent) × (body weight in kg/height in m^2)], with a potential range of 0–18.[17]

Construct validity measures (cross-sectional and longitudinal)

Instrumental Activity of Daily Living (IADL) difficulty in AAH covered eight items (preparing meals, shopping for groceries, managing money, making phone calls, doing light housework, doing heavy housework, getting to places outside walking distance, and managing medications) from the Second Longitudinal Study on Aging[18] and Lawton and Brody[19] and was scored as the number of tasks for which the respondent reported difficulty performing or unable to perform it without help. IADL difficulty in BLSA included seven of the eight AAH items except getting to places outside walking distance and was scored as the number of tasks for which the respondent reported difficulty performing or unable to perform without help.

Hospitalization was based on respondent reports of one or more overnight hospitalizations in the year prior to Wave 4 (2004) and Wave 10 (2010) in AAH and of one or more overnight hospitalizations in the year prior to each respondent's NHANES interview (1999–2002).

For gait speed in AAH, a 3 m or 4 m course in participants' homes was used, with participants instructed to walk at their usual pace, as if walking to the store. The average walking speed (m/s) for two trials was used to create a dichotomous variable for gait speed average of <0.8 vs. ≥ 0.8 m/s. A walk course was set up in the testing centre to measure time to complete a 20 ft walk (seconds) in NHANES.

The short physical performance battery (SPPB) measure of lower body performance is based on three component tasks: standing balance, repeated chairs stands, and usual walking speed.[20] Each component task was scored as 0–4 (0 = *worst* to 4 = *best*), and a composite score was computed as the sum of scores on component tasks as 0–12 (0 = *worst* to 12 = *best*). Complete details on the composite SPPB score in AAH are provided by Miller and colleagues.[21]

Chair stands in AAH were measured as the time (maximum of 60 s) it took participants to complete five rises and returns when instructed to complete the task as fast as possible.

Grip strength testing in AAH was performed in the self-reported stronger hand using either a Jamar (Preston Corp, Jackson, MI) or a baseline (Fabrication Enterprises, Inc., Irvington, NY) isometric dynamometer (pre-testing showed equivalent results using either instrument) and defined as the average (kg) of three maximal trials. Grip strength testing in BLSA was done for both hands and scored as the average (kg) of three trials for each hand separately.

Knee extensor strength testing in NHANES was done using a Kin Com MP dynamometer (Chattanooga Group, Inc., Chattanooga, TN). Peak torque (Newton/metres) of the quadriceps was measured at 60°/s.

Frailty in AAH was measured using the FRAIL scale.[11] FRAIL includes five components: fatigue, resistance, ambulation, illness, and loss of weight. FRAIL scores range from 0 to 5 (i.e. 1 point for each component; 0 = *best* to 5 = *worst*).

Vital status up to 6 years later in AAH was determined by proxy report as part of the annual AAH follow-up interview plus tracing via local databases (e.g. obituaries). Results were coded 1 for decedents and 0 for survivors. Vital status up to 9.75 years later in BLSA was coded 1 for decedents and 0 for survivors.

Statistics

Data were analysed using IBM SPSS Statistics, version 21 (Somers, NY). Descriptive statistics are reported as means ± standard deviations, median and interquartile range, or percentages. *T*-test for continuous variables and chi-square for categorical variables were used to compare socio-demographic characteristics of study groups. Internal consistency reliability was evaluated using Cronbach's alpha. Principal components analysis was performed to investigate the homogeneity of SARC-F items. SARC-F associations with muscle mass, SPSM, and frailty were examined using Spearman's rho correlation. Analysis of covariance (continuous outcomes) and logistic regression (dichotomous outcomes) were used to compare participants with SARC-F scores ≥ 4 vs. < 4 in cross-sectional outcomes. Linear regression (continuous outcomes) and logistic regression (dichotomous outcomes) were used to examine the association of SARC-F score ≥ 4 vs. < 4 for longitudinal outcomes and for SARC-F items with cross-sectional and longitudinal outcomes. Means ± standard deviations are reported for analyses of covariance, adjusted odds ratios (ORs) and 95% confidence

Table 1 Demographic characteristics among participants with high (≥4) vs. low (<4) SARC-F scores

	SARC-F scores ≥ 4		
African American Health	Yes (n = 157)	No (n = 696)	P-value*
Age (mean ± SD)	59.95 ± 4.5	59.00 ± 4.3	0.013
Women (%)	71.3	60.6	0.012
Years of education (mean ± SD)	11.57 ± 2.8	12.69 ± 2.9	<0.001
Annual household income below 25 K (%)	77.1	44.1	<0.001
City area (%)	55.4	42.7	0.004
Self-rated health: fair or poor (%)	81.5	26.3	<0.001
	SARC-F scores ≥ 4		
Baltimore Longitudinal Study of Aging	Yes (n = 66)	No (n = 987)	P-value*
Age (mean ± SD)	72.74 ± 8.7	85.35 ± 9.2	<0.001
Women (%)	60.6	46.6	0.019
Race (%)			0.019
White	89.4	74.4	
Black or African American	10.6	21.0	
Other race	0	4.6	
Years of education (mean ± SD)	15.33 ± 3.0	16.81 ± 2.7	<0.001
Annual household income below 25 K (%)	16.7	4.9	0.011
Self-rated health: fair or poor (%)	38.6	4.2	<0.001
	SARC-F scores ≥ 4		
National Health and Nutrition Examination Survey	Yes (n = 505)	No (n = 2783)	P-value*
Age (mean ± SD)	75.76 ± 8.2	71.30 ± 7.8	<0.001
Women (%)	66.5	49.1	<0.001
Race (%)			0.711
Mexican American	18.4	19.9	
Other Hispanic	4.8	3.9	
Non-Hispanic White	57.0	58.2	
Non-Hispanic Black	17.4	16.0	
Other race	2.4	2.1	
Education (%)			<0.001
Less than high school	55.2	40.8	
High school/GED	20.2	24.1	
More than high school	24.6	35.1	
Annual household income below 20 K (%)	54.5	33.1	<0.001

GED, general educational development; SD, standard deviation.
*T-test for continuous variables and chi-square for categorical variables.

Table 2 Construct validity: cross-sectional comparisons for health outcomes among participants with high (≥4) vs. low (<4) SARC-F scores

	SARC-F scores ≥ 4		
African American Health	Yes	No	P-value*
IADLs (0–8)	3.67 ± 2.0	0.42 ± 0.9	<0.001
Chair stands (s)	15.25 ± 5.2	11.30 ± 3.5	<0.001
Grip strength (kg)	26.23 ± 11.1	32.52 ± 11.6	<0.001
Short physical performance battery (0–12)	4.78 ± 3.1	8.90 ± 2.3	<0.001
	Odds ratio (95% CI)		P-value*
Hospitalized overnight in the past year	3.94 (2.66–5.83)		<0.001
Gait speed < 0.8 m/s	5.73 (3.28–10.00)		<0.001
	SARC-F scores ≥ 4		
Baltimore Longitudinal Study of Aging	Yes	No	P-value*
IADLs (0–7)	3.74 ± 2.4	0.23 ± 0.7	<0.001
Grip strength, right hand (kg)	17.92 ± 8.4	29.62 ± 10.2	0.004
Grip strength, left hand (kg)	16.80 ± 8.1	28.25 ± 10.1	0.012
	SARC-F scores ≥ 4		
National Health and Nutrition Examination Survey	Yes	No	P-value*
20 ft walk (s)	10.18 ± 4.9	6.86 ± 2.58	<0.001
Peak force, knee extensor strength	198.21 ± 69.4	258.15 ± 88.77	<0.001
	Odds ratio (95% CI)		P-value*
Hospitalized overnight in the past year	2.53 (2.01–3.19)		<0.001

CI, confidence interval; IADLs, Instrumental Activities of Daily Living.
*Analysis of covariance for continuous outcomes and logistic regression for dichotomous outcomes. Analyses adjusted for age and gender.

DOI: 10.1002/jcsm.12048

intervals (CIs) are reported for logistic regression analyses, and unstandardized (B) regression coefficients and standard errors are reported for linear regression analyses. Cross-sectional analyses were adjusted for age and gender, and longitudinal analyses were adjusted for age, gender, and baseline values of all validating variables except mortality.

Results

SARC-F total scores (0–10) median (interquartile range) were 0 (0–2) in AAH, 0 (0 and 1) in BLSA, and 0 (0–2) in NHANES. There were 18.4% (157/853) AAH, 6.3% (66/1053) BLSA, and 15.4% (505/3288) NHANES participants with a SARC-F score ≥ 4

Table 3 Construct validity: cross-sectional comparisons for health outcomes with SARC-F items*

African American Health			Baltimore Longitudinal Study of Aging		
	Unstandardized coefficients			Unstandardized coefficients	
	B (SE)	*P*-value		B (SE)	*P*-value
IADLs (0–8)			IADLs (0–7)		
Strength	1.55 (0.06)	<0.001	Strength	1.68 (0.07)	<0.001
Assistance walking	1.97 (0.07)	<0.001	Assistance walking	1.76 (0.07)	<0.001
Rise from a chair	1.88 (0.08)	<0.001	Rise from a chair	1.39 (0.07)	<0.001
Climb stairs	1.65 (0.06)	<0.001	Climb stairs	1.48 (0.06)	<0.001
Falls	0.92 (0.10)	<0.001	Falls	0.52 (0.07)	<0.001
Chair stands (s)			Grip strength, right hand (kg)		
Strength	1.89 (0.26)	<0.001	Strength	−2.77 (0.63)	<0.001
Assistance walking	2.76 (0.37)	<0.001	Assistance walking	−2.17 (0.62)	<0.001
Rise from a chair	2.98 (0.39)	<.001	Rise from a chair	−1.95 (0.60)	0.001
Climb stairs	2.35 (0.27)	<0.001	Climb stairs	−1.81 (0.59)	0.002
Falls	1.21 (0.29)	<0.001	Falls	−0.69 (0.46)	0.131
Grip strength (kg)			Grip strength, left hand (kg)		
Strength	−2.70 (0.46)	<0.001			
Assistance walking	−1.53 (0.57)	0.007	Strength	−2.60 (0.62)	<0.001
Rise from a chair	−1.77 (0.58)	0.002	Assistance walking	−1.71 (0.63)	0.007
Climb stairs	−2.53 (0.48)	<0.001	Rise from a chair	−1.83 (0.58)	0.002
Falls	−1.12 (0.57)	0.051	Climb stairs	−1.65 (0.57)	0.004
			Falls	−0.10 (0.44)	0.815
SPPB (0–12)					
Strength	−2.03 (0.13)	<0.001			
Assistance walking	−2.73 (0.17)	<0.001			
Rise from a chair	−2.37 (0.18)	<0.001			
Climb stairs	−2.33 (0.13)	<0.001			
Falls	−1.35 (0.18)	<0.001			

			National Health and Nutrition Examination Survey		
				Unstandardized coefficients	
	Odds ratio (95% CI)	*P*-value		B (SE)	*P*-value
Hospitalized overnight in the past year			20 ft walk (s)		
Strength	2.14 (1.73–2.65)	<0.001	Strength	1.38 (0.09)	<0.001
Assistance walking	2.36 (1.85–3.02)	<0.001	Assistance walking	3.21 (0.22)	<0.001
Rise from a chair	1.98 (1.54–2.56)	<0.001	Rise from a chair	1.55 (0.11)	<0.001
Climb stairs	2.09 (1.67–2.62)	<0.001	Climb stairs	1.44 (0.09)	<0.001
Falls	1.97 (1.49–2.59)	<0.001	Falls	0.93 (0.10)	<0.001
Gait speed < 0.8 m/s			Peak force, knee		
Strength	2.65 (1.96–3.59)	<0.001	Strength	−16.43 (3.07)	<0.001
Assistance walking	5.02 (2.75–9.15)	<0.001	Assistance walking	−32.87 (8.42)	<0.001
Rise from a chair	2.92 (1.96–4.36)	<0.001	Rise from a chair	−24.22 (3.72)	<0.001
Climb stairs	3.07 (2.21–4.24)	<0.001	Climb stairs	−21.89 (3.16)	<0.001
Falls	1.49 (1.11–1.99)	0.008	Falls	−14.12 (3.28)	<0.001
				Odds ratio (95% CI)	*P*-value
			Hospitalized overnight in the past year		
			Strength	1.75 (1.54–1.99)	<0.001
			Assistance walking	1.77 (1.44–2.17)	<0.001
			Rise from a chair	1.68 (1.45–1.94)	<0.001
			Climb stairs	1.73 (1.52–1.97)	<0.001
			Falls	1.62 (1.41–1.86)	<0.001

CI, confidence interval; IADLs, Instrumental Activities of Daily Living; SE, standard error; SPPB, short physical performance battery.
* Linear regression for continuous outcomes and logistic regression for dichotomous outcomes. Analyses adjusted for age and gender.

DOI: 10.1002/jcsm.12048

(SARC-F positive). The characteristics of the SARC-F positive and SARC-F negative groups are shown in *Table* 1 and demonstrated the expected findings (e.g. lower household income in the SARC-F positive group). The five-item SARC-F alphas were 0.81 (AAH), 0.78 (BLSA), and 0.76 (NHANES). The principal components SARC-F analyses yielded a single factor that accounted for 57.2% (AAH), 56.7% (BLSA), and 53.5% (NHANES) of variance. SARC-F item loadings (AAH, BLSA, and NHANES) were as follows: strength (0.81, 0.80, 0.76), assistance walking (0.81, 0.84, 0.76), rise from a chair (0.80, 0.76, 0.80), climb stairs (0.81, 0.88, 0.80), and falls (0.50, 0.39, 0.49). SARC-F in the AAH cohort correlated with Tanita lean mass per cent ($r = -0.20$; $P = 0.001$), Tanita lean mass total (lbs; $r = -0.07$, $P = 0.046$), and the SPSM ($r = -0.34$; $P < 0.001$).

Cross-sectional results

Health outcomes (disability, physical performance, strength, and utilization) for those with SARC-F ≥ 4 vs. < 4 in the AAH, BLSA, and NHANES cohorts are shown in *Table* 2. AAH participants with SARC-F scores ≥ 4 had more IADL deficits than those with SARC-F scores of 3 or less, slower chair stands times, lower grip strength, and lower SPPB scores ($P_s \leq 0.001$). SARC-F scores ≥ 4 in AAH also were associated with a higher likelihood of being hospitalized overnight in the past year and having a gait speed of <0.8 m/s ($P_s \leq 0.001$). The correlation between total SARC-F scores (0–10) and FRAIL scale scores (0–5) was 0.70 ($P < 0.001$) in AAH. SARC-F scores ≥ 4 in BLSA were associated with higher IADL difficulties and worse grip strength in both the right and left hands ($P_s \leq 0.001$). NHANES participants with SARC-F scores ≥ 4 exhibited slower times to walk 20 ft, lower strength (knee extension), and increased likelihood of being hospitalized overnight in the past year ($P_s \leq 0.001$). Similar associations were seen in cross-sectional comparisons for SARC-F items and outcomes in AAH, BLSA, and NHANES (*Table* 3).

Longitudinal results

SARC-F scores ≥ 4 predicted hospitalization and gait speed of <0.8 m/s at 6 year follow-up in the AAH ($P_s \leq 0.05$; *Table* 4). SARC-F scores ≥ 4 were also associated with more IADL deficits, slower chair stands times, and lower SPPB scores ($P_s \leq 0.01$) at 6 year follow-up in AAH. Grip strength was lower for those with SARC-F scores ≥ 4 (27 ± 12) vs. < 4 (32 ± 11) at 6 year follow-up in AAH, but this difference was not statistically significant ($P = 0.288$). AAH SARC-F scores ≥ 4 predicted 6 year mortality (OR = 1.87, 95% CI 1.17–2.98; $P = 0.009$) and included 19.7% of persons who died compared with 11.9% of non-SARC-F positive persons who died. SARC-F scores ≥ 4 were associated with more IADL deficits, lower grip strength right hand, and lower grip strength left hand ($P_s \leq 0.05$) at follow-up in BLSA. SARC-F scores ≥ 4 vs. < 4 also predicted mortality (OR = 3.0, 95% CI 1.57–5.73; $P < 0.001$) in BLSA. Mortality for BLSA participants was 39.4% for SARC-F ≥ 4 vs. 8.0% for SARC-F < 4. A mortality analysis including only BLSA participants with at least 2 years of follow-up yielded similar results for SARC-F scores ≥ 4 vs. < 4 (OR = 2.69, 95% CI 1.39–5.21; $P < 0.001$). Similar associations were seen in longitudinal comparisons for SARC-F items and outcomes in AAH and BLSA (*Table* 5).

Discussion

This study demonstrated that a simple clinical score, SARC-F, predicts clinically significant outcomes over the subsequent

Table 4 Construct validity: longitudinal comparisons for health outcomes among participants with high (≥4) vs. low (<4) SARC-F scores*

African American Health	SARC-F scores ≥ 4	
	Odds ratio (95% CI)	*P*-value*
Hospitalized overnight in the past year	2.43 (1.46–4.05)	<0.001
Gait speed < 0.8 m/s	2.46 (1.13–5.34)	0.023
Mortality	1.87 (1.17–2.98)	0.009
	Unstandardized coefficients B (SE)	*P*-value*
Instrumental Activities of Daily Living (IADLs; 0–8)	0.78 (0.27)	0.004
Chair stands (s)	3.14 (1.1)	0.004
Grip strength (kg)	−1.07 (1.0)	0.288
Short physical performance battery (0–12)	−0.29 (0.08)	<0.001
Baltimore Longitudinal Study of Aging	**SARC-F scores ≥ 4**	
	Unstandardized coefficients B (SE)	*P*-value*
IADLs (0–7)	1.24 (0.22)	<0.001
Grip strength, right hand (kg)	−2.44 (1.19)	0.041
Grip strength, left hand (kg)	−2.96 (1.26)	0.019
	Odds ratio (95% CI)	*P*-value*
Mortality	3.00 (1.57–5.73)	<0.001

CI, confidence interval; SE, standard error.
*Linear regression for continuous outcomes and logistic regression for dichotomous outcomes. Mortality analyses adjusted for age and gender. All other analyses adjusted for age, gender, and baseline value of the outcome variable being examined.

Table 5 Construct validity: longitudinal comparisons for health outcomes with SARC-F items*

African American Health	Unstandardized coefficients B (SE)	*P*-value
IADLs		
Strength	0.53 (0.13)	<0.001
Assistance walking	−0.04 (0.17)	0.820
Rise from a chair	0.44 (0.16)	0.005
Climb stairs	0.78 (0.15)	<0.001
Falls	0.15 (0.13)	0.246
Chair stands (s)		
Strength	1.10 (0.60)	0.070
Assistance walking	2.46 (0.90)	0.007
Rise from a chair	1.78 (0.86)	0.039
Climb stairs	1.06 (0.65)	0.107
Falls	0.08 (0.58)	0.898
Grip strength (kg) Mortality		
Strength	−0.40 (0.55)	0.473
Assistance walking	−0.39 (0.68)	0.561
Rise from a chair	−0.91 (0.64)	0.161
Climb stairs	−0.22 (0.57)	0.703
Falls	−0.37 (0.63)	0.559
Short physical performance battery (0–12)		
Strength	−0.68 (0.22)	0.002
Assistance walking	−0.45 (0.30)	0.131
Rise from a chair	−1.06 (0.25)	<0.001
Climb stairs	−1.05 (0.23)	<0.001
Falls	0.11 (0.24)	0.649
	Odds ratio (95% CI)	*P*-value
Hospitalized overnight in the past year		
Strength	1.67 (1.27–2.21)	<0.001
Assistance walking	1.55 (1.11–2.17)	0.010
Rise from a chair	2.06 (1.51–2.83)	<0.001
Climb stairs	1.52 (1.13–2.05)	0.006
Falls	1.83 (1.29–2.59)	<0.001
Gait speed < 0.8 m/s		
Strength	1.33 (0.87–2.02)	0.182
Assistance walking	1.43 (0.78–2.62)	0.254
Rise from a chair	1.71 (1.00–2.92)	0.050
Climb stairs	1.50 (0.96–2.35)	0.077
Falls	0.79 (0.52–1.21)	0.278
Mortality		
Strength	1.43 (1.11–1.85)	0.005
Assistance walking	1.43 (1.07–1.90)	0.015
Rise from a chair	1.26 (0.92–1.75)	0.147
Climb stairs	1.59 (1.21–2.02)	<0.001
Falls	1.04 (0.74–1.49)	0.807
Baltimore Longitudinal Study of Aging	**Unstandardized coefficients B (SE)**	***P*-value**
IADLs (0–7)		
Strength	0.30 (0.11)	0.007
Assistance walking	0.74 (0.11)	<0.001
vRise from a chair	0.44 (0.10)	<0.001
Climb stairs	0.29 (0.11)	0.007
Falls	0.10 (0.07)	0.151
Grip strength, right hand (kg)		
Strength	−1.32 (0.62)	0.035
Assistance walking	−0.94 (0.62)	0.129
Rise from a chair	−1.56 (0.56)	0.006
Climb stairs	−1.18 (0.59)	0.045
Falls	−0.15 (0.37)	0.695
Grip strength, left hand (kg)		
Strength	−0.18 (0.69)	0.800
Assistance walking	−1.17 (0.70)	0.097
Rise from a chair	−1.99 (0.59)	<0.001
Climb stairs	−0.78 (0.65)	0.229
Falls	−0.49 (0.39)	0.215

(Continues)

Table 5 (Continued)

	Odds ratio (95% CI)	*P*-value
Mortality		
Strength	1.89 (1.30–2.74)	<0.001
Assistance walking	1.30 (0.91–1.84)	0.145
Rise from a chair	1.64 (1.12–2.39)	0.011
Climb stairs	1.45 (1.03–2.04)	0.035
Falls	1.26 (0.86–1.84)	0.244

CI, confidence interval; IADLs, Instrumental Activities of Daily Living; SE, standard error.
* Linear regression for continuous outcomes and logistic regression for dichotomous outcomes. Mortality analyses adjusted for age and gender. All other analyses adjusted for age, gender, and baseline value of the outcome variable being examined.

6 years in AAH and BLSA. The components of SARC-F are those that would be expected to be associated with poor muscle function. Thus, it is not surprising that cross-sectional SARC-F correlates with knee strength (NHANES) and grip strength (AAH and BLSA). SARC-F also correlates and with frailty on the self-reported FRAIL scale (AAH). The objective of case finding is to identify persons at high risk for adverse outcomes. Based on these findings, SARC-F would be an adequate tool to identify persons with muscle weakness that may be amenable to treatment. At present, the major treatment would be resistance exercise and possibly other forms of exercise coupled with increased protein intake.[22–25] This study suggests that SARC-F is a rapid, question-based clinical tool that may be a useful sarcopenia screen for primary care physicians. This would then allow referral of persons with positive SARC-F scores for further evaluation and to involve them in resistance exercise programmes.[26,27] Testosterone may be useful, but its safety has been questioned.[28] A number of drugs such as selective androgen receptor molecules, myostatin inhibitors, and ghrelin agonists are being developed to treat sarcopenia[29]; if and when proven effective, they may benefit SARC-F positive patients.

This approach is similar to the one emerging for fracture risk. Two studies have shown that using the questions included in the FRAX risk assessment tool (www.shef.ac.uk/FRAX), the population can be divided into low risk, intermediate risk, and high risk.[30] If BMD is only measured in those at intermediate risk, the need to measure BMD is avoided in 70% of the population. Selective use of BMD testing had a sensitivity of 87% for identifying fragility fractures. As commonly used definitions of sarcopenia require low gait speed and an appendicular muscle mass corrected for height squared, it would seem that those who are SARC-F positive might need to undergo this more extensive testing.

This study has limitations. There were some differences in the items used to construct the SARC-F in AAH and BLSA vs. NHANES. In particular, the SARC-F falls item computed using the NHANES cohort data did not include the number of falls in the past year but rather whether respondents had balance problems or falling problems in the past year. NHANES respondents with falling problems may have had fewer than four falls in the past year, and those who report balance problems but not falling problems may not have had any falls in the past year. Thus, we were not able to determine the number of falls for NHANES respondents, so we were only able to approximate the SARC-F falls item and scoring in NHANES via self-reported balance or falling problems. Some outcomes were not available in all cohorts, or the valid sample size was too small for some outcomes to be included in this study. Another limitation is that the AAH cohort included late middle-aged adults at baseline, so the prevalence of sarcopenia among African Americans likely would be higher in an older cohort. On the other hand, late middle age is probably a good time to identify sarcopenia so that it can be stabilized or reversed in time to prevent adverse outcomes, and African Americans are more likely to have frailty.[31] The BLSA cohort does include older adults, but this group is high functioning when enrolled in the study. SARC-F correlations with the performance-based SPSM (AAH) and with muscle mass by bioelectrical impedance (AAH) were modest overall. Thus, additional studies are needed to examine SARC-F's validity in other populations and against standard definitions of sarcopenia (e.g. European Working Group on Sarcopenia in Older People) in prospective studies and to investigate the ability of treatment programs to lower SARC-F scores or prevent adverse outcomes in patients with SARC-F positive. There are currently no data available on the optimal interval or age to screen for sarcopenia. Empirical evidence is also needed to demonstrate that sarcopenia interventions have efficacy for clinical outcomes prior to screening for this syndrome in primary care.

In summary, we developed a simple self-report questionnaire (SARC-F) to screen for persons with sarcopenia. The SARC-F includes five items based on cardinal features or consequences of sarcopenia. This study provides evidence that the SARC-F scale in AAH, BLSA, and NHANES cohorts is internally consistent and valid for detecting persons at risk for adverse outcomes from sarcopenia.

Acknowledgements

This research was supported in part by a grant from the National Institute on Aging to Dr D. K. Miller (R01 AG010436) and in part by the Intramural Research Program of the National Institute on Aging. The authors of this manuscript certify that they comply with the guidelines of ethical authorship and publishing as stated in the Journal of Cachexia, Sarcopenia, and Muscle 2010; 1:7–8 (von Haehling S, Morley JE, Coats AJ, and Anker SD).

Conflict of interest

None declared.

References

1. Rolland Y, Czerwinski S, Abellan van Kan G, Morley JE, Cesari M, Onder G, *et al*. Sarcopenia: its assessment, etiology, pathogenesis, consequences and future perspectives. *J Nutr Health Aging* 2008; **12**: 433–450.
2. Morley JE, Baumgartner RN, Roubenoff R, Mayer J, Nair KS. Sarcopenia. *J Lab Clin Med* 2001; **137**: 231–243.
3. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, *et al*. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010; **39**: 412–423.
4. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, *et al*. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International Working Group on Sarcopenia. *J Am Med Dir Assoc* 2011; **12**: 249–256.
5. Morley JE, Abbatecola AM, Argiles JM, Baracos V, Bauer J, Bhasin S, *et al*. Sarcopenia with limited mobility: an international consensus. *J Am Med Dir Assoc* 2011; **12**: 403–409.
6. Mitchell WK, Williams J, Atherton P, Larvin M, Lund J, Narici M. Sarcopenia, dynapenia, and the impact of advancing age on human skeletal muscle size and strength: a qualitative review. *Front Physiol* 2012; **3**: 260.
7. Manini TM, Clark BC. Dynapenia and aging: an update. *J Gerontol A Biol Sci Med Sci* 2012; **67**: 28–40.
8. Bouchard DR, Janssen I. Dynapenic-obesity and physical function in older adults. *J Gerontol A Biol Sci Med Sci* 2010; **65**: 71–77.
9. Johansson H, Kanis JA, Oden A, Johnell O, McCloskey E. BMD, clinical risk factors and their combination for hip fracture prevention. *Osteoporos Int* 2009; **20**: 1675–1682.
10. Leslie WD, Morin S, Lix LM, Johansson H, Oden A, McCloskey E, *et al*. Fracture risk assessment without bone density measurement in routine clinical practice. *Osteoporos Int* 2012; **23**: 75–85.
11. Morley JE, Malmstrom TK, Miller DK. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. *J Nutr Health Aging* 2012; **16**: 601–608.
12. Miller DK, Wolinsky FD, Malmstrom TK, Andresen EM, Miller JP. Inner city, middle-aged African Americans have excess frank and subclinical disability. *J Gerontol A Biol Sci Med Sci* 2005; **60**: 207–212.
13. Malmstrom TK, Miller DK, Herning MM, Morley JE. Low appendicular skeletal muscle mass (ASM) with limited mobility and poor health outcomes in middle-aged African Americans. *J Cachexia Sarcopenia Muscle* 2013; **4**: 179–186.
14. Malmstrom TK, Morley JE. Sarcopenia: the target population. *J Frailty Aging* 2013; **2**: 55–56.
15. Schrack JA, Simonsick EM, Chaves PH, Ferrucci L. The role of energetic cost in the age-related slowing of gait speed. *J Am Geriatr Soc* 2012; **60**: 1811–1816.
16. US Department of Health and Human Services. National Center for Health Statistics. In The National Health and Nutrition Examination Survey: Sample Design, 1999–2006. Washington, DC: Centers for Disease Control and Prevention; 2012.
17. Miller DK, Malmstrom TK, Andresen EM, Miller JP, Herning MM, Schootman M, *et al*. Development and validation of a short portable sarcopenia measure in the African American Health project. *J Gerontol A Biol Sci Med Sci* 2009; **64A**: 388–394.
18. National Center for Health Statistics. Data File Documentation, National Health Interview Second Supplement on Aging, 1994 (Machine Readable Data File and Documentation). Hyattsville, MD: National Center for Health Statistics; 1998.
19. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist* 1969; **9**: 179–186.
20. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, *et al*. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994; **49**: M85–M94.
21. Miller DK, Wolinsky FD, Andresen EM, Malmstrom TK, Miller JP. Adverse outcomes and correlates of change in the Short Physical Performance Battery over 36 months in the African American Health project. *J Gerontol A Biol Sci Med Sci* 2008; **63**: 487–494.
22. Singh NA, Quine S, Clemson LM, Williams EJ, Williamson DA, Stavrinos TM, *et al*. Effects of high-intensity progressive resistance training and targeted multidisciplinary treatment of frailty on mortality and nursing home admissions after hip fracture: a randomized controlled trial. *J Am Med Dir Assoc* 2012; **13**: 24–30.
23. Malafarina V, Uriz-Otano F, Iniesta R, Gil-Guerrero L. Effectiveness of nutritional supplementation on muscle mass in treatment of sarcopenia in old age: a systematic review. *J Am Med Dir Assoc* 2013; **14**: 10–17.
24. Candow DG, Forbes SC, Little JP, Cornish SM, Pinkoski C, Chilibeck PD. Effect of nutritional interventions and resistance exercise on aging muscle mass and strength. *Biogerontology* 2012; **13**: 345–358.
25. Montero-Fernandez N, Serra-Rexach JA. Role of exercise on sarcopenia in the elderly. *Eur J Phys Rehabil Med* 2013; **49**: 131–143.
26. Cesari M, Vellas B. Sarcopenia: a novel clinical condition or still a matter for research? *J Am Med Dir Assoc* 2012; **13**: 766–767.
27. Morley JE, Argiles JM, Evans WJ, Bhasin S, Cella D, Deutz NE, *et al*. Nutritional recommendations for the management of sarcopenia. *J Am Med Dir Assoc* 2010; **11**: 391–396.
28. Morley JE. Anabolic steroids and frailty. *J Am Med Dir Assoc* 2010; **11**: 533–536.
29. Rolland Y, Onder G, Morley JE, Gillette-Guyonet S, Abellan van Kan G, Vellas B. Current and future pharmacologic treatment of sarcopenia. *Clin Geriatr Med* 2011; **27**: 423–447.
30. Kanis JA, McCloskey E, Johansson H, Oden A, Leslie WD. FRAX (®) with and without bone mineral density. *Calcif Tissue Int* 2012; **90**: 1–13.
31. Hirsch C, Anderson ML, Newman A, Kop W, Jackson S, Gottdiener J, *et al*. The association of race with frailty: the cardiovascular health study. *Ann Epidemiol* 2006; **16**: 545–553.