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A Comparison of Four Frailty Models

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Abstract

OBJECTIVES—To determine how well the interview-based, clinic-friendly International Academy of Nutrition and Aging (FRAIL) frailty scale predicts future disability and mortality in the African American Health (AAH) cohort compared with the clinic-friendly Study of Osteoporotic Fractures (SOF) frailty scale, the phenotype-based Cardiovascular Health Study (CHS) frailty scale, and the comprehensive Frailty Index (FI).

DESIGN—Longitudinal cohort study.

SETTING—Metropolitan St. Louis, Missouri.

PARTICIPANTS—African American Health is a population-based panel study of African Americans (baseline age 49–65) from St. Louis, Missouri. Participants completed in-home assessments at baseline (N = 998) and 3- (n = 853) and 9- (n = 582) year follow-up.

MEASUREMENTS—Outcomes included activity of daily living (ADL) and instrumental ADL difficulties at 3 and 9 years and 9-year mortality. Frailty measures included the FRAIL, SOF, and CHS scales and the FI.

RESULTS—The FRAIL, SOF, CHS, and FI measures predicted new 3- and 9-year disability, and the FRAIL and FI scales predicted 9-year mortality. Receiver operating characteristic (ROC) contrasts showed that the FRAIL scale performed as well as (9-year disability and mortality) or better than (3-year disability) the CHS and SOF scales and the FI better than the FRAIL, CHS, and SOF scales for all outcomes except the FRAIL and CHS scales for 9-year ADL difficulties. The CHS and SOF scales were equivalent for all outcomes in ROC contrasts.

CONCLUSION—Overall the FI and the FRAIL scale exhibited the strongest predictive validity for disability and mortality in AAH. The best prediction tool to identify frail individuals at risk of

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disability and mortality may be one that includes a comorbidity measure. The FRAIL scale includes a comorbidity item and is a brief interview-based measure that is easy to administer, score, and interpret. The FRAIL scale has demonstrated validity and may prove to be a valuable scale for use by clinicians.

Keywords

frailty; ADLs; IADLs; mortality; African American

Frailty is a condition that places older persons at risk of poor outcomes when exposed to stressful events.¹ Frailty is present in approximately 5% of the population aged 60 and older.² Numerous studies have suggested that frailty is a predictor of functional deterioration and mortality.^{3–5} Models of frailty have been developed using three different domains: functional, deficit accumulation, and biological.^{6–11} The Frailty Index (FI) was developed based on the concept that deficit accumulation—a combination of symptoms, diseases, conditions, and disability—can predict frailty.⁹ A biological model of frailty based on five components—weight loss, exhaustion, low energy expenditure, slowness, and weakness—is known as the Cardiovascular Health Study (CHS) scale.¹² The Study of Osteoporotic Fractures (SOF) scale included one functional and two biological factors in its frailty index—inability to rise from a chair five times without using the arms, weight loss, and reduced energy level.¹³ The CHS and FI measures are not practical for use in a busy clinic. The CHS scale requires measured performance (walking speed, grip strength) and is scored based on relative values in a population. The FI includes numerous items, typically 40 or more, and may include measured performance (e.g., cognition, physical performance). The SOF scale is brief and easy to administer in a clinic but requires measured performance (chair stands).

The FRAIL scale was recently developed as a simple measure that combines components of functional, deficit accumulation, and biological frailty models.^{14,15} The FRAIL scale was constructed to include only interview questions and require minimal administration time so that physicians and other health professionals can easily use it in clinical practice. Initial studies have shown that the FRAIL scale predicts adverse health outcomes,^{16–18} but research directly comparing different models of frailty is limited,^{19,20} and these studies have not included the FRAIL scale.

African Americans have a higher level of functional impairment and disability than do Caucasians²¹ and have been shown to have a higher prevalence of frailty than Caucasians using the CHS model.²² Thus there is a need for a brief frailty tool that can be used to identify African Americans at risk of disability and mortality so that early interventions can be developed. African American Health (AAH) is a population-based study of late middle-aged African Americans from two socioeconomically diverse areas of St. Louis. The AAH population has been demonstrated to have excess disability²¹ and represents a population that could benefit greatly from early frailty identification by clinicians.

The objective of this study was to investigate how well the interview-based, clinic-friendly FRAIL scale predicts future disability and mortality compared with the clinic-friendly SOF scale, the phenotype-based CHS scale, and the comprehensive FI in the AAH cohort. It was hypothesized that the FRAIL, CHS, and SOF measures and the FI would have predictive

validity for disability and mortality and that the predictive validity of the FRAIL scale for disability and mortality would be similar to that of the SOF and CHS scales and the FI using receiver operating characteristic (ROC) contrasts.

METHODS

Study Sample

African American Health has been described in detail previously.²¹ In brief, it is a population-based panel study of African Americans from two socioeconomically diverse areas of St. Louis. Participants were born between 1936 and 1950 and were aged 49 to 65 at the Wave 1 baseline assessment. Inclusion criteria involved community-dwelling, self-reported black or African-American race, and Mini-Mental State Examination (MMSE) scores of 16 or greater. Recruitment proportion (participants/enumerated eligible persons) was 76%. Wave 1 was conducted at participants' homes in 2000/01. Interviewers completed 26 hours of training on study-specific interviewing and physical performance measurements. In-home assessments were repeated 36 months after baseline during Wave 4 in 853 of the 947 survivors (90.1%). In-home assessments also were repeated 9 years after baseline during Wave 10 in 582 of the 835 surviving participants (70%). The analytical sample for this report includes 779 baseline respondents with valid scores on all frailty scales in analyses that include only respondents with no dependency in any baseline activity of daily living (ADL). The institutional review board at Saint Louis University approved this study.

Frailty Scales

The FRAIL scale includes five components: fatigue, resistance, ambulation, illness, and loss of weight.^{14,15} FRAIL scale scores range from 0 to 5 (one point for each component; 0 = best to 5 = worst) and represent frail (3–5), prefrail (1–2), and robust (0) health status. AAH Wave 1 data were used to construct the FRAIL scale for this study. Fatigue was measured by asking respondents how much time during the previous 4 weeks they felt tired, with responses of all of the time or most of the time scored one point. Resistance was assessed by asking participants whether they had any difficulty walking up 10 steps alone without resting and without aids and ambulation by asking whether they had any difficulty walking several hundred yards alone and without aids; yes responses were each scored as one point. Illness was scored 1 for respondents who reported five or more illnesses out of 11 total. Loss of weight was scored 1 for respondents with a weight decline of 5% or more within the previous 12 months. Fatigue and weight loss represent biological factors, resistance and ambulation represent function, and illness represents deficit accumulation.

The CHS scale consists of five components—unintentional weight loss, exhaustion, low activity, weakness, and slowness—and scores range from 0 to 5.¹² A modified 0 to 5 CHS scale was constructed using AAH Wave 1 available variables. Weight loss of 5% or more in the previous year was scored as one point. Feeling tired all or most of the time in the previous 4 weeks was scored as one point. Yale Physical Activity Scale²³ scores in the lowest quintile stratified according to sex (<16 for women, <17.2 for men) were coded as one point. The lowest quintile of grip strength stratified according to sex and body mass index (BMI) quartiles (female: BMI < 26.61 kg/m² and grip strength < 22 kg, BMI 26.61–

30.89 kg/m and grip strength < 22 kg, BMI 30.89–36.10 kg/m² and grip strength < 24 kg, BMI > 36.10 kg/m² and grip strength < 20 kg; male: BMI < 24.54 kg/m² and grip strength < 32.2 kg, BMI 24.54–27.60 kg/m² and grip strength < 35.4 kg, BMI > 27.6–30.68 kg/m² and grip strength < 39.1 kg, BMI > 30.68 kg/m² and grip strength < 35.5 kg) was scored as one point. Reporting a lot of difficulty or being unable to walk for one-quarter of a mile was scored as one point. CHS scale scores are classified as follows: frail (3–5), prefrail (1–2), and robust (0) health status.

SOF includes three items (weight loss, chair stands, energy level), with a score range of 0 to 3.²⁰ SOF items were scored as weight loss of 5% or more in the previous year (one point), inability to complete five consecutive chair rises (one point), and reported having a lot of energy in the previous 4 week none or a little of the time (one point). SOF scale scores are categorized as frail (2–3), prefrail (1), and robust (0).

The FI was constructed using a standardized procedure²⁴ and included 25 items from the AAH study. A summary score (0–25; one point per item) was used to construct the FI as total score/25 (0–1). FI items included self-rated health; difficulty walking several hundred yards, walking 1 mile, climbing one flight of stairs, climbing several flights of stairs, doing moderate activities, and doing vigorous activities; accomplished less than would like because of physical health, cut down on time spent at work or other activities because of emotional problems, did not feel full of life, felt downhearted and depressed, and felt tired in the past 4 weeks; restless sleep in the past week; diabetes mellitus; stroke; heart attack; cancer; chronic obstructive pulmonary disease; heart failure; angina pectoris; asthma; kidney disease; MMSE worst quintile; and Falls Efficacy Scale worst quintile. FI scores are classified as frail (>0.25), prefrail (0.25–0.20), and robust (<0.20).

Outcomes

Disability was assessed using ADL scales. ADL difficulties included seven items (0–7; bathing, dressing, eating, transferring bed or chair, walking across a room, getting outside, and using toilet).²⁵ One or more new ADL difficulties at 3 and 9 years was coded as 1. IADL difficulties included eight items (0–8; preparing meals, shopping for groceries, managing money, making telephone calls, doing light housework, doing heavy housework, getting to places out-side walking distance, and managing medications).^{25,26} One or more new IADL difficulties at 3 and 9 years was coded as 1. ADL and IADL items were obtained at baseline and 3 and 9 years. Mortality was determined by tracking efforts throughout the study, including contacting proxies, search of multiple databases, and visits to the last known neighborhood. Deaths were coded as 1.

Statistical Analysis

Data were analyzed using SPSS Statistics version 20.0 (IBM Corp., Somers, NY) and SAS version 9.2 (SAS Institute, Inc., Cary, NC). Descriptive statistics are reported as means ± standard deviations (SD) or percentages. SPSS logistic regression was used to investigate the associations between each frailty scale category (frail, prefrail, robust (reference)) with study outcomes. Odds ratios were adjusted for age and sex (AORs), and 95% confidence intervals (CIs) are reported for logistic regression. SAS was used to generate receiver

operator characteristic (ROC) curves and ROC contrasts to compare the area under the ROC curve (AUC) for study outcomes of the frailty scales. Frailty scale total scores for FRAIL (0–5), CHS (0–5), SOF (0–3), and FI (0–1) were used for ROC curve analyses. Sensitivity analyses were conducted including participants with baseline ADL dependencies (n = 834) and by examining outcomes according to tertiles for age. Results did not differ substantively for sensitivity analyses, so only the main analyses (n = 779) are presented.

RESULTS

Participant baseline age according to tertile was 51.4 ± 1.1 (n = 263), 56.0 ± 1.5 (n = 254), and 61.5 ± 2.0 (n = 262), and the percentages of participants aged 60 and older were 26%, 46%, and 95% at baseline and 3- and 9-year follow-up, respectively. Classification at baseline on the FRAIL, SOF, and CHS scales and the FI was 42.0%, 32.0%, 51.6%, and 9.4%, respectively, for prefrail and 6.4%, 9.2%, 6.3%, and 22.6%, respectively, for frail. Table 1 demonstrates that frail or prefrail status on all scales predicted one or more new ADL difficulties at 3 and 9 years (except for FI prefrail at 9 years). AUC comparisons for frailty scales show that the FI (AUC = 0.75) was more predictive of one or more new ADL difficulties at 3-year follow-up than all other scales and that the FRAIL scale (AUC = 0.71) performed better than the CHS (AUC = 0.64) and SOF (AUC = 0.63) scales (Figure 1A). The FI (AUC = 0.69) and the FRAIL scale (AUC = 0.68) were better predictors than the SOF scale (AUC = 0.62) and equivalent to the CHS scale (AUC = 0.66) for one or more new ADL difficulties at 9-year follow-up (Figure 1B).

Table 1 shows that frail or prefrail status on all scales predicted one or more new IADL difficulties at 3 and 9 years. The FI (AUC = 0.75) was a better predictor of one or more new IADLs at 3 years than the FRAIL (AUC = 0.69), CHS (AUC = 0.63), and SOF (AUC = 0.61) scales, and the FRAIL scale outperformed the CHS and SOF scales (Figure 1C). For one or more new IADL difficulties at 9 years, the FI (AUC = 0.70) was superior to the FRAIL (AUC = 0.62), CHS (AUC = 0.60), and SOF (AUC = 0.63) scales (Figure 1D). There were no differences between the FRAIL, CHS, and SOF scales.

Table 2 shows the predictive values of scales for 9-year mortality. Frail status on the FI and the FRAIL scale predicted mortality, but prefrail status did not. The mortality ROC curves are shown in Figure 1D. The FI (AUC = 0.64) was a better predictor than the FRAIL (AUC = 0.57), CHS (AUC = 0.53), and SOF (AUC = 0.53) scales.

DISCUSSION

In AAH, prefrail or frail status according to the FRAIL, SOF, and CHS scales and the FI predict new disability; and frail status on the FI and the FRAIL scale predicts mortality. Contrary to the first hypothesis, frail status on the CHS and SOF scales and prefrail status on all measures do not predict mortality, although the AORs are in the expected direction. The European Male Aging Study of men aged 40 to 79 has also shown that prefrail and frail status on the FRAIL, CHS, and FI measures predict mortality.¹⁸ Another recent longitudinal study in a Chinese cohort of adults aged 65 and older showed that total FRAIL, CHS, and FI scale scores are associated with physical limitations and mortality.¹⁶ Overall initial studies

with the FRAIL indicate that this interview-only tool has good predictive validity for disability and mortality across diverse population groups.

ROC contrasts for the AUC show that the simple FRAIL is a better predictor of new disability at 3 years than the CHS and SOF scales and at least an equivalent predictor of 9-year disability and mortality. The FRAIL scale includes a comorbidity item (which the CHS and SOF scales do not), which may explain these findings. The FI demonstrated better predictive validity than any of the other scales for new disability and mortality except new ADL difficulties at 9 years in ROC contrasts. The comprehensive FI^{9,24} captures the critical components of the FRAIL, CHS, and SOF scales in addition to other important health outcomes (e.g., falls, mood, cognition), which may be why it has superior predictive validity for disability and mortality. The CHS and SOF scales did not differ in any ROC contrast. Equivalent AUCs for the CHS and SOF measures, including mortality and disability, have also been reported in the prediction of adverse health outcomes.^{19,20} One explanation for this is that the SOF physical performance item (chair stands) could provide predictive capacity akin to the CHS low activity, weakness, and slowness components.

This study has limitations. The late middle-age AAH cohort results may not generalize to an older population of African Americans, although sensitivity analyses did not reveal substantive differences across age tertiles. Study outcomes were limited to disability and mortality. The AUCs indicate only a moderate ability of frailty measures to discriminate outcomes. Future research should include older African Americans and other outcomes such as fractures, falls, hospitalization, and institutionalization. Cut points of greater than 0.21 (frail),¹⁸ 0.13 to 0.21 (prefrail), and 0 to 1.12 (robust)¹⁸ or 0.25 or greater (frail) and less than 0.25 (robust)²⁷ have previously been used to categorize the FI. Slightly different cut points were used in the present study, which may have influenced the results of hypothesis 1.

The FRAIL meets criteria for a scale that would make a successful diagnostic test of frailty.²⁸ Specifically, it shows strong content (face validity) by including factors that investigators have considered to represent the basic principles necessary to define frailty. Construct validity has been demonstrated because the FRAIL correlates with measures of disability even when they are excluded as part of the definition.¹⁷ This is important because frailty is not the same as disability.²⁹ The FRAIL scale has also been shown to correlate with self-rated health and falls efficacy.¹⁷ Predictive validity exists in that the FRAIL scale predicts new disabilities and mortality.^{16–18} The FRAIL scale is clinically sensible³⁰ in that it is easily used and useful in that it earmarks areas of potential treatment, and it can be broadly acceptable to a general practitioner audience.

In conclusion, the FI and the FRAIL scale exhibited the strongest predictive validity for new disability and mortality in AAH. The best prediction tool to identify frail individuals at risk of disability and mortality may be one that includes a comorbidity measure. The FRAIL scale is brief; is interview based; is easy to administer, score, and interpret; includes a comorbidity measure; and has demonstrated validity, so it may prove to be valuable for use by clinicians in the office.

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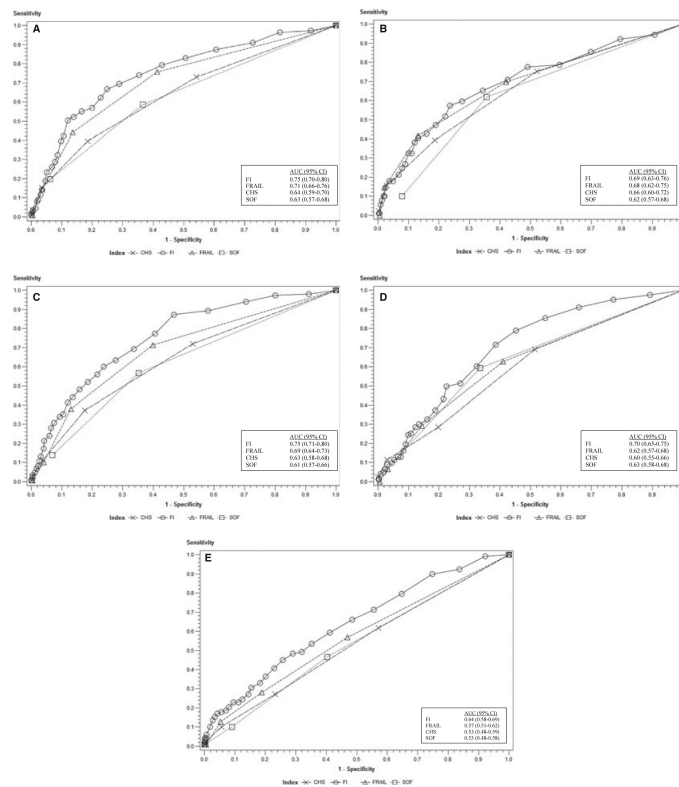


Figure 1.

(A) One or more new activity of daily living (ADL) difficulties at 3 years. Receiver operating characteristic (ROC) contrasts: Frailty Index (FI) versus International Academy of Nutrition and Aging (FRAIL) frailty scale, $P = .047$; FI versus Cardiovascular Health Study (CHS) frailty scale, $P < .001$; FI versus Study of Osteoporotic Fractures (SOF) frailty scale, $P < .001$; FRAIL scale versus CHS scale, $P = .002$; FRAIL scale versus SOF scale, $P < .001$; CHS scale versus SOF scale, $P = .62$. (B) One or more new ADL difficulties at 9 years. ROC contrasts: FI versus SOF scale, $P = .03$; FRAIL scale versus SOF scale, $P = .03$; FI versus FRAIL scale, $P = .71$; FI versus CHS scale, $P = .22$; FRAIL versus CHS scale, $P = .31$; CHS scale versus SOF scale, $P = .30$. (C) One or more new instrumental activity of daily living (IADL) difficulties at 3 years. ROC contrasts: FI versus FRAIL scale, $P < .001$; FI versus CHS scale, $P < .001$; FI versus SOF scale, $P < .001$; FRAIL scale versus CHS scale, $P = .02$; FRAIL scale versus SOF scale, $P < .001$; CHS scale versus SOF scale, $P = .40$. (D) One or more new IADL difficulties at 9 years. ROC contrasts: FI versus FRAIL scale, $P < .001$; FI versus CHS scale, $P < .001$; FI versus SOF scale, $P = .01$; FRAIL scale versus CHS scale, $P = .38$, FRAIL scale versus SOF scale, $P = .72$; CHS scale versus SOF scale, $P = .28$. (E) 9-year mortality. ROC contrasts: FI versus FRAIL scale, $P = .001$; FI versus CHS scale, $P < .001$; FI versus SOF scale, $P < .001$; FRAIL scale versus CHS scale, $P = .22$; FRAIL scale versus SOF scale, $P = .10$; CHS scale versus SOF scale, $P = .92$.

Table 1

Frailty Measures and Disability

Measure	1 New Activity of Daily Living Difficulties		1 New Instrumental Activity of Daily Living Difficulties	
	3-Year, n = 668	9-Year, n = 470	3-Year, n = 667	9-Year, n = 457
	Adjusted Odds Ratio (95% Confidence Interval) P-Value			
International Academy of Nutrition and Aging (FRAIL) frailty scale				
Prefrail	4.14 (2.5–6.8) <.001	2.82 (1.7–4.8) <.001	3.56 (2.4–5.4) <.001	2.29 (1.5–3.6) <.001
Frail	10.25 (4.7–22.3) <.001	14.93 (5.6–40.0) <.001	5.07 (2.4–10.6) <.001	3.08 (1.2–8.1) .02
Study of Osteoporotic Fractures (SOF) frailty scale				
Prefrail	1.98 (1.3–3.1) .004	3.18 (1.9–5.3) <.001	2.23 (1.5–3.3) <.001	2.79 (1.8–4.4) <.001
Frail	5.19 (2.8–9.8) <.001	2.36 (1.0–5.50) .047	2.94 (1.6–5.4) .001	3.22 (1.6–6.7) .002
Cardiovascular Health Study (CHS) frailty scale				
Prefrail	1.94 (1.2–3.1) .005	2.38 (1.4–4.1) .002	2.05 (1.4–3.1) .001	1.84 (1.2–2.9) .009
Frail	7.11 (3.3–15.2) <.001	10.39 (4.2–25.9) <.001	4.49 (2.2–9.3) <.001	5.60 (2.3–13.7) <.001
Frailty Index (FI)				
Prefrail	2.28 (1.1–4.7) .03	2.04 (0.9–4.4) .07	2.55 (1.4–4.7) .003	2.19 (1.1–4.3) .02
Frail	7.90 (4.9–12.7) <.001	5.00 (2.9–8.6) <.001	5.58 (3.6–8.6) <.001	2.94 (1.8–4.9) <.001

Logistic regression adjusted for age and sex. Reference category is robust health status for each measure.

Table 2

Frailty Measures and Mortality (N = 779)

Measure	Adjusted Odds Ratio (95% Confidence Interval)	P-Value	Mortality, %
International Academy of Nutrition and Aging (FRAIL) frailty scale			
Robust	1 (reference)		12.7
Prefrail	1.45 (0.94–2.23)	.09	15.9
Frail	3.24 (1.62–6.47)	<.001	30.0
Study of Osteoporotic Fractures (SOF) frailty scale			
Robust	1 (reference)		13.8
Prefrail	1.36 (0.89–2.10)	.26	17.3
Frail	1.42 (0.71–2.84)	.32	16.7
Cardiovascular Health Study (CHS) frailty scale			
Robust	1 (reference)		13.7
Prefrail	1.21 (0.79–1.84)	.38	15.2
Frail	1.95 (0.93–4.09)	.08	24.5
Frailty Index (FI)			
Robust	1 (reference)		11.5
Prefrail	1.77 (0.92–3.41)	.08	19.2
Frail	2.28 (1.46–3.55)	<.001	24.4

Logistic regression adjusted for age and sex.