ORIGINAL ARTICLE

Prevalence of weakness and its relationship with limitations based on the Foundations for the National Institutes for Health project: data from the Health and Retirement Study

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BACKGROUND/OBJECTIVES: The objectives of this study were to determine the prevalence of muscle weakness using the two 2014 Foundation for the National Institutes of Health (FNIH) Sarcopenia Project criteria and its relationship with physical limitations, basic activities of daily living (ADL) and instrumental ADL.

SUBJECTS/METHODS: We performed a cross-sectional analysis of community-dwelling adults from the Health and Retirement Study 2006–2008 and identified a subsample of 5092 adults aged ≥ 60 years with grip strength (GS) data. Self-reported physical limitations, basic ADL and instrumental ADL were assessed. Criteria for GS (men < 26 kg; women < 16 kg) and GS adjusted for body mass index (GS/BMI; men < 1.0; women < 0.56) were applied to the sample. We determined the prevalence of muscle weakness in each sex. Multivariable logistic regression was used to calculate the association of physical limitations, basic ADL and instrument ADL with weakness definitions in each sex.

RESULTS: Mean age was 72.1 years (54.9% female). Mean GS was 38.3 and 22.9 kg and mean BMI was 29 kg/m^2, respectively, in men and women. Weakness prevalence using GS and GS:BMI definitions were 7.8 and 15.2 ($P < 0.001$), respectively, in men and 11.4 and 13.3% ($P = 0.04$) in women. Overall prevalence of physical limitations, basic ADL limitations and instrumental ADL limitations was 52.9, 28.1 and 35.9%, respectively. In those with weakness, prevalence of physical limitations, basic ADL and instrumental ADL was 78.5, 42.3 and 65.3%, respectively, using the GS definition, and 79.7, 40.7 and 58.8%, respectively, using the GS/BMI definition. GS and the GS/BMI definitions of weakness were strongly associated with physical limitations (odds ratio (OR) 2.19 (95% confidence interval (CI): (1.67–2.87)) and 2.52 (2.01–3.17)), basic ADL (OR 1.59 (1.22–2.07) and 1.66 (1.32–2.07)) and instrumental ADLs (OR 1.98 (1.28–2.54) and 1.78 (1.44–2.20)).

CONCLUSIONS: The new FNIH guidelines for weakness are associated with higher prevalence of physical limitations, basic ADL impairments and instrumental ADL impairments as compared with individuals without weakness.

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INTRODUCTION

Age-related muscle loss begins in the third to fourth decade of life.[1] Although some loss of muscle and strength, termed sarcopenia, is a normal part of aging, clinically significant sarcopenia associated with functional impairment is thought to be a cornerstone in the process of frailty and disability.[1] Although weakness was initially considered to be a direct consequence of the loss of muscle mass,[2] it may also be mediated through loss of muscle strength.[3,4] Emerging evidence suggests that there may be two distinct subgroups of persons with weakness: one due to low appendicular muscle mass, and the other due to reduced strength with intact muscle mass.[5]

There have been considerable discrepancies in the definitions of sarcopenia in the literature[6,7] largely because of the different etiologies of clinical weakness. Recently, the Foundations for the National Institutes of Health (FNIH) published criteria for sarcopenia specifically for use in clinical practice[5] to identify individuals that consisted of using muscle strength and muscle mass. This group based their cutoffs on a classification and regression tree analysis using grip strength (GS) to predict slow gait speed, a clinical measure known to strongly predict incident disability and mortality.[8] GS cutoff points were based on eight pooled studies in men and women.[9] Our goal was to (a) illustrate the prevalence of clinically defined weakness in a representative population, by applying these new recommendations to a wave of subjects from the Health and Retirement Study; (b) observe the degree of impairment in those fulfilling such cutoffs; and (c) describe the association between the FNIH cutoffs and physical limitations, basic ADL impairment and instrumental ADL impairment.

MATERIALS AND METHODS

The Health and Retirement Study (HRS) is a nationally representative survey of community-dwelling adults aged 50 years and older conducted by the University of Michigan. The initial HRS sample was drawn in 1992 from a multi-stage, clustered area probability design of households, with individuals with birth years between 1931 and 1941. Data from the 2006 and 2008 waves were combined for this particular cross-sectional

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analysis.[10] All eligible respondents consenting to enhanced face-to-face interviews were included in the analysis. Study design and sampling procedures are available online (http://hrsonline.isr.umich.edu). The study has been funded by the National Institutes on Aging, and because of the de-identified nature of the data the local Institutional Review Boards of our institutions have exempted this study from review purposes.

There were 10 615 participants aged ⩾ 60 years who consented to the enhanced face-to-face interview. Respondents were excluded if GS or body mass index (BMI) were missing (*n* = 5523). Our final analytical sample consisted of 5092 subjects. We included persons of all races and ethnicities. Years of education and smoking status were obtained by self-report questionnaire. We created a comorbidity index ranging from 0 to 8, which was meant to reflect self-reported health conditions, including, cancer, diabetes, heart failure, hypertension, lung disease, arthritis, myocardial infarction and stroke.[10] Physical activity was assessed using a questionnaire during the HRS interview, the details of which are described online. Subjects were classified as being physically active if they engaged in moderate or vigorous physical activity at least once per week.

Measures

Weight was measured using a Healthometer 830KL (Medstock, Miami, Queensland, Australia) scale and rounded to the half pound, and converted to kilograms. HRS did not measure subjects with a weight > 136.4 kg, as this exceeded the capacity of the scale. Height was measured using a stadiometer with the respondent standing without shoes or socks and their heels and shoulders touching the wall. BMI was calculated as weight (in kg) divided by height, in meters squared. Waist circumference was assessed using a tape measure at the level of the umbilicus while standing. The measure was recorded at the end of exhalation after a deep breath. High waist circumference was determined using cutoffs of 88 and 102 cm in women and men, respectively.[11] Walking speed was used as a marker in the FNIH criteria. In HRS, it was measured in m/s and measured as respondents walked a 98.5-inch course two times (there and back). Participants were instructed to wear appropriate footwear (low or no heal), and the interviewer walked to the side and slightly behind the respondent. The measure could be completed with a walking aid. The interview used a stop watch to time the respondent.

GS was measured using a Smedley spring-type hand dynamometer (TTM, Tokyo, Japan). In right-handed individuals, values from the dominant hand were used. In the case of ambidextrous and left-handed individuals, the higher of the values from either hand was used.[12] All measurements were taken with the subject in a standing position, with their arm at their side at a 90° angle. Two measurements were taken with each hand and averaged across trials. The highest average score from either hand was used. We classified subjects as having weakness based on the 2014 FNIH Sarcopenia Project guidelines.[5] GS < 26 and < 16 kg were considered as having weakness in men and women, respectively. As this consensus group suggested two independent definitions, we also classified subjects as having weakness if their GS divided by BMI ratio (GS/BMI) was < 1.0 and < 0.56 in men and women, respectively.

Functional impairment was assessed using self-reported questionnaires classifying the subject's ability in terms of physical limitations, basic activities of daily living (ADL) and instrumental ADL. Physical limitations were defined by the inability or difficulty in performing two or more of the following tasks, as described in our previous publication:[10] walking several blocks, walking 1 block, sitting 2 h, getting up from a chair, climbing stairs, climbing one flight of stairs, stooping, reaching arms, pulling or pushing large objects, lifting weights or picking up a dime. Individuals with one or more difficulties in bathing, dressing, eating, toileting or getting out of bed were considered to have an ADL limitation. Last, subjects reporting difficulties with at least one of the following were considered to have an instrumental ADL limitation: managing money, preparing meals, requiring help with house or yard work, using the phone or taking medications.

Statistical analysis

Continuous variables are presented as means (s.e.), and categorical values as counts (%). *T*-tests compared baseline characteristics between sexes for continuous variables, and χ^2 for categorical variables. Subjects were classified as having weakness using the aforementioned definitions. Overall and sex-specific prevalence estimates of weakness are presented for both FNIH definitions, and a *t*-test compared the mean differences between them. We stratified these results by ethnicity (white, black and other), and by three age categories (60–69.9, 70–79.9 and ⩾ 80 years).

Prevalence of overall and sex-specific physical impairments (physical limitations, basic ADL limitations and instrumental ADL limitations) were determined for the overall cohort, and by ethnicity and age group. The prevalence of limitations by weakness status was evaluated using each definition.

The primary aim of this study was to determine the association of the two FNIH definitions of weakness (GS and GS/BMI) and physical limitations, basic ADL limitations and instrumental ADL limitations. Overall and sex-specific unadjusted and adjusted logistic regression models were constructed to ascertain the association of each definition with the degree of impairment. We adjusted for age, race, number of years of schooling completed, smoking status, comorbidity and physical activity status. For the overall cohort, we adjusted for sex as well. Odds ratios and 95% confidence intervals are presented. We determined the relationship between walking speed in those with and without weakness based on each respective sarcopenia definition, stratified by sex, ethnicity and age group. All data were managed and processed using SAS software version 9.3 (SAS Institute, Cary, NC), and results were weighted using HRS respondent-level weights for physical measures, which includes adjustments for sample selection probability and nonresponse. A *P*-value < 0.05 and confidence intervals excluding 1.0 were considered statistically significant.

RESULTS

Baseline characteristics are shown in Table 1. Differences were observed in most characteristics between men and women. GS and walking speed differed between sexes (*P* < 0.001), as were the mean number of physical limitations. Table 2 represents the prevalence of weakness based on the FNIH criteria of reduced GS and reduced GS:BMI ratios in the overall cohort, by ethnicity and by age group. Overall prevalence rates using GS were higher in women than in men (11.4% vs 7.8%; *P* < 0.001) but higher in men (15.2 vs 13.3%; *P* = 0.05) using GS:BMI. This was generally seen across ethnic and age categories. Stratifying by sex, prevalence rates were generally higher using GS:BMI than GS. Notably, the prevalence of weakness increased with age.

We determined the prevalence of physical limitations, basic ADL limitations and Instrumental ADL limitations by overall cohort, sex, ethnicity and by age group. The prevalence of physical limitations in men was 44.7% and in women it was 59% (Table 3). Higher prevalence rates of physical limitations, basic ADL and instrumental ADL were observed in blacks and by increasing age. Figure 1 represents the prevalence of limitations in men and women in those with weakness, depending on the definition used. The prevalence rates in both sexes suggest that rates of physical limitations are highest in those with weakness (irrespective of definition) followed by instrumental ADL and basic ADL impairments. Mean walking speed was uniformly lower in those with weakness, irrespective of the FNIH definition, sex, ethnicity and age (Figure 2; Supplementary Appendix 1). Analysis of individuals excluded in this study were less likely to be white, had higher comorbidity burden, higher waist circumference and higher mean number of physical limitations (Supplementary Appendix 2). Full details of subanalyses can be seen in Supplementary Appendix 3. We additionally present crude data on the relationship between BMI, GS and limitations by sex in Supplementary Appendix 4. A bimodal relationship occurs between BMI and limitations with higher rates in underweight and obese individuals, whereas the relationship between GS and BMI appears more linear.

Univariate and multivariate analyses are shown in Table 4. The strength of association across all limitations (physical, instrumental ADL and basic ADL) was higher in those with sarcopenia. The strengths of association were higher in women in physical limitations, and lower in instrumental ADL. Minimal differences were observed between sexes in basic ADLs. We observed reduced odd ratios after adjusting for all of our covariates across all models.

Table 1. Characteristics of subjects of HRS aged ⩾ 60 years

	Overall N = 5092	Men N = 2195	Women N = 2897	P-value
Age (years)	72.1 (7.9)	71.9 (7.5)	72.1 (8.1)	0.37
Education (years)	12.4 (3.1)	12.6 (3.3)	12.3 (2.9)	< 0.001
Race				
White	4308 (84.6)	1901 (86.6)	2407 (83.1)	< 0.001
Black	619 (12.2)	272 (10.1)	397 (13.7)	< 0.001
Other	165 (3.2)	72 (3.3)	93 (3.2)	0.10
Current smoker (%)	582 (11.4)	259 (11.8)	323 (11.2)	< 0.001
Number of comorbidities[a]	2.02 (1.21)	2.0 (1.3)	2.1 (1.2)	< 0.01
Grip strength (kg)	29.5 (10.6)	38.3 (9.1)	22.9 (5.8)	< 0.001
Walking speed (m/s)[b]	2.46 (0.86)	2.61 (0.85)	2.34 (0.84)	< 0.001
Waist circumference (cm)	100.3 (14.0)	104.7 (11.5)	96.9 (14.7)	< 0.001
High waist circumference (%)[c]	3229 (63.4)	1200 (54.7)	2029 (70.0)	< 0.001
Body mass index (kg/m^2)	28.7 (5.5)	28.9 (4.7)	28.7 (6.0)	0.20
Obesity (BMI ⩾ 30 kg/m^2)	1849 (36.7)	790 (36.1)	1059 (37.2)	< 0.001
Mean number of physical limitations	2.5 (2.5)	1.9 (2.26)	2.9 (2.6)	< 0.001
Physically active[d]	3062 (60.2)	1451 (66.2)	1611 (55.7)	< 0.001

Abbreviation: HRS, Health and Retirement Study. [a]Comorbidities (hypertension, diabetes, lung disease, stroke, cancer, MI, CHF and arthritis). [b]Walking speed was available for 3849 participants. [c] ⩾ 88 cm in women; ⩾ 102 cm in men. [d]Physically active was defined as participation in moderate/vigorous activity at least 1 per week. All values represented are means (s.d.) or counts (percentages).

Table 2. Prevalence of FNIH weakness in Health and Retirement Survey by definition in those aged ⩾ 60 years

	GS			P-value	GS:BMI			P-value	GS	Vs	GS:BMI
	Overall	Men	Women		Overall	Men	Women		Overall	Men	Women
Overall cohort	503 (9.9)	172 (7.8)	331 (11.4)	< 0.001	719 (14.1)	334 (15.2)	385 (13.3)	0.05	< 0.001	< 0.001	0.04
Ethnicity											
White	438 (10.2)	147 (7.7)	291 (12.1)	< 0.001	601 (14.0)	286 (15.0)	315 (13.1)	0.07	< 0.001	< 0.001	0.33
Black	48 (7.8)	17 (7.8)	31 (7.8)	0.95	87 (14.1)	34 (15.3)	53 (13.4)	0.50	< 0.01	< 0.01	0.02
Other	17 (10.3)	8 (11.1)	9 (9.7)	0.76	31 (18.8)	14 (19.4)	17 (18.3)	0.85	0.04	0.20	0.12
Age group (years)											
60–69	80 (3.6)	28 (2.9)	52 (4.1)	0.13	201 (9.0)	89 (9.3)	112 (8.9)	0.73	< 0.001	< 0.001	< 0.001
70–79	173 (9.0)	60 (7.1)	113 (10.6)	0.01	291 (15.2)	142 (16.7)	149 (14.0)	0.09	< 0.001	< 0.001	0.03
80	250 (26.3)	84 (21.8)	166 (29.4)	0.01	227 (23.9)	103 (26.7)	124 (22.0)	0.09	0.29	0.16	0.04

Abbreviations: FNIH, Foundation for the National Institutes of Health; GS, Grip Strength; GS/BMI, Grip Strength divided by BMI. All values are represented as counts (weighted percentages). *P*-value compares the prevalence within each subgroup between prevalence using GS vs prevalence using GS/BMI. Grip strength cutoffs are < 16 kg in women and < 26 kg in men, and GS/BMI is < 1.0 in men and < 0.56 in women. GS/BMI represents grip strength (in kg) divided by body mass index.

DISCUSSION

We demonstrate that the prevalence of clinical weakness is high in a representative population but differ by sex and by FNIH definition used. Our results confirm that the rates of limitations are higher in individuals with weakness, irrespective of the definition used. We also observed that a strong association exists between weakness and limitations, more so in women than in men.

FNIH definitions are meant to identify those at risk for weakness.[5] The study results were readily apparent using the GS:BMI ratio compared with the GS alone, paralleling those observed using the FNIH muscle mass cutoff points alone in our other work.[13] Although both definitions have been used to classify sarcopenia, a shift from using muscle mass to muscle strength (using GS) has been advocated as the prime determinant for studying sarcopenia. This is in direct contrast to the FNIH consensus, suggesting that GS was the best predictor in men, and GS/BMI was better in women in terms of model fit statistics.

We believe that GS:BMI accounts for both strength and in part muscle mass, and that this measure should be considered in clinical practice for identification of sarcopenia. Previous research has also suggested different associations between strength and mobility across BMI[14] requiring the need to adjust for this measure. While BMI traditionally has been used for assessment of obesity, in older adults, it has low sensitivity for measuring fat as it also accounts for muscle mass. No consistent trends were observed in basic or instrumental ADLs across definitions, likely because these definitions are meant to identify individuals at risk for impairments rather than impairments themselves.

Sex-specific differences have been observed in other studies,[5,10,13] including a mortality analysis in older adults.[13] Part of this reasoning is because of sex-specific differences of the normative population-based data for GS.[14–16] Our data suggest that physical limitations and instrumental ADL in those with classified weakness (irrespective of definition) were markedly

Table 3. Prevalence of limitations in Health and Retirement Study in those aged ⩾ 60 years

Definition	Overall			Males			Females		
	Physical[a] N = 5092	Basic[b] N = 2998	Instrumental[c] N = 4873	Physical[a] N = 2195	Basic[b] N = 1086	Instrumental[c] N = 2080	Physical[a] N = 2897	Basic[b] N = 1912	Instrumental[c] N = 2793
Overall cohort	2691 (52.9)	837 (28.1)	1740 (35.9)	981 (44.7)	336 (31.0)	609 (29.5)	1710 (59.0)	501 (26.5)	1131 (40.7)
Ethnicity									
White	2238 (52.0)	650 (26.2)	1434 (35.0)	853 (44.9)	284 (30.4)	517 (29.0)	1385 (57.5)	366 (23.7)	917 (39.7)
Black	372 (60.1)	158 (38.7)	258 (43.4)	102 (46.0)	46 (39.3)	78 (36.5)	270 (68.0)	112 (38.5)	180 (47.2)
Other	81 (49.1)	29 (31.9)	48 (30.0)	26 (36.1)	6 (18.8)	14 (20.6)	55 (59.1)	23 (39.0)	34 (37.0)
Age group (years)									
60–69	1019 (45.8)	286 (25.1)	547 (25.6)	356 (37.1)	101 (26.6)	186 (20.4)	513 (50.5)	127 (21.2)	273 (27.7)
70–79	1009 (52.6)	318 (26.9)	674 (36.7)	394 (46.4)	138 (29.6)	250 (31.2)	499 (55.6)	132 (22.4)	345 (39.7)
80+	663 (69.8)	233 (35.6)	519 (59.0)	231 (59.8)	97 (40.9)	173 (48.9)	432 (76.6)	136 (32.6)	346 (65.9)

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living. [a]Physical Limitations were defined by inability or difficulty in performing two or more of the following tasks: walking several blocks, walking 1 block, sitting for 2 h, getting up from the chair, climbing stairs, climbing one flight of stairs, stooping, reaching arms, pulling/pushing large objects, lifting weights and picking up a dime. [b]Basic ADL impairments are defined as difficulty or inability with at least 1: bathing, dressing, eating, toileting or getting out of bed. [c]Instrumental ADL impairments are defined as difficulty or inability with at least 1: preparing meals, managing money or needing help with house or yard work, using the phone or taking medication. All values are represented as counts (weighted percentages).
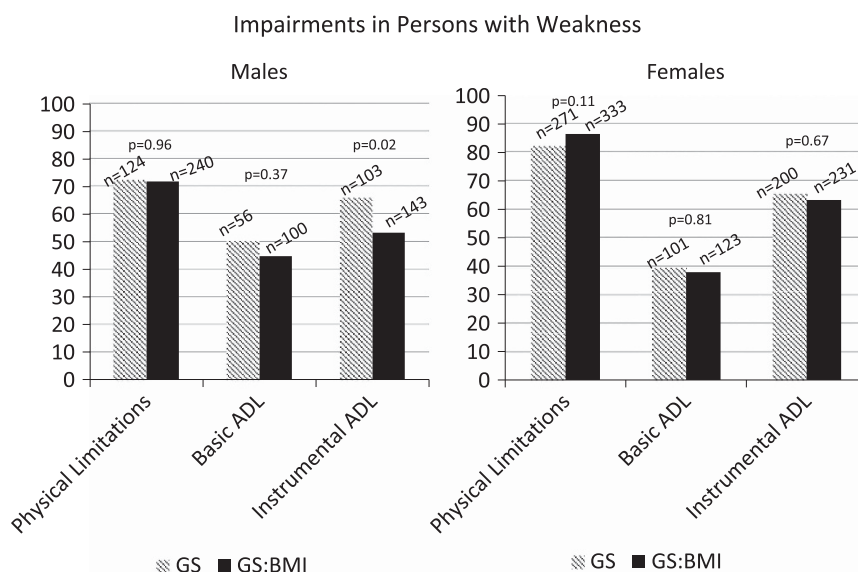

Figure 1. Prevalence of impairments (physical limitations, basic activities of daily living and instrumental activities of daily living) in subjects with weakness aged ⩾ 60 years in the Health and Retirement Survey 2006–2008, based on the Foundation for the National Institutes on Health Sarcopenia Project Guidelines. *P*-values represent the differences between grip strength and grip strength:body mass index definitions.

higher in women than in men. Although purely hypothetical, women tend to gain more fat and have lower absolute muscle mass with age, placing them at a greater risk of developing obesity and lower muscle strength with aging.[4,17] Consequences of obesity in women may be more significant than in men because of greater loss of existing lower muscle stores leading to incremental limitations in movement. Further, the female population had high central adiposity, which can be associated with higher degrees of functional impairment.

There are several significant limitations in this study. First, information on chronic illnesses, smoking status, race and physical limitations were all obtained by self-report, which has the potential for inaccuracies. Second, sampling bias is likely and may affect our results despite the survey's intention to be a representative sample of older adults. Third, we created a comorbidity score incorporating the number of disorders, each of which was given an equal weighting. However, we deliberately presented our unadjusted results, which suggested that the odds ratios remained significant. Fourth, we analyzed a cross-sectional cohort of persons. Fifth, our cohort was predominantly white, making generalizations to other races very difficult. We presented data on black and other as an exploratory analysis; however, we recognize that drawing definitive conclusions is not possible and should be interpreted with caution. There are ethnic differences in body composition, which may explain some of the discordance in our results. The FNIH studies were based predominantly on Caucasian subjects, although there were subgroups examined that consisted of African-American and Hispanic origin. Recalibration of cutoff points and definitions may be needed for these groups, paralleling the approach used in the Framingham Risk score or

Mean Gait Speed by FNIH Definition
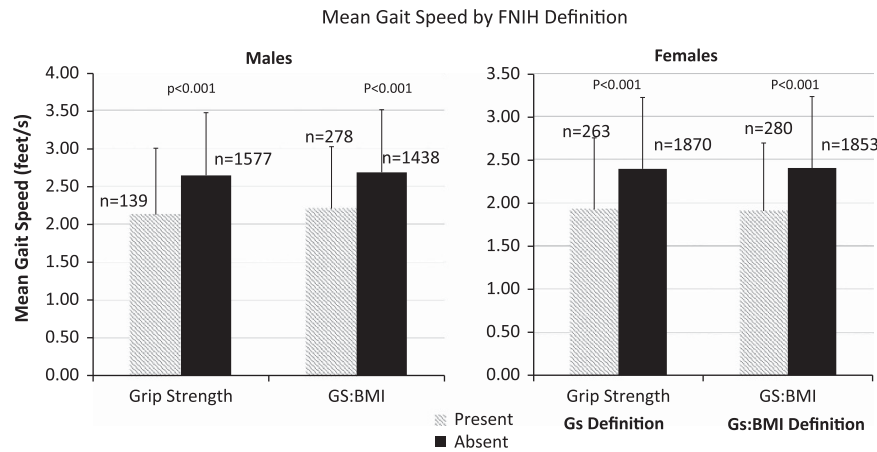
Figure 2. Mean walking speed in subjects with and without Sarcopenia aged ⩾ 60years in the Health and Retirement Survey 2006–2008, based on the Foundation for the National Institutes on Health Sarcopenia Project Guidelines. Error bars represent s.d.'s. *P*-values represent the differences between individuals with and without weakness (depending on the definition used).

Table 4. Association of impairment (physical, ADL and IADL) and FNIH cutoff

		Overall (n = 5092)		Men (n = 2195)		Women (n = 2897)	
		Unadjusted	Adjusted[a]	Unadjusted	Adjusted	Unadjusted	Adjusted
Physical	GS	3.91 (3.06–5.01)	2.19 (1.67–2.87)	4.03 (2.72–5.99)	1.98 (1.28–3.05)	3.58 (2.61–4.91)	2.34 (1.66–3.30)
Limitations	GS/BMI	4.44 (3.58, 5.52)	2.52 (2.01, 3.17)	4.02 (3.00, 5.39)	2.14 (1.57, 2.91)	5.86 (4.18, 8.22)	3.59 (2.51, 5.13)
Basic	GS	2.15 (1.68, 2.76)	1.59 (1.22, 2.07)	1.54 (0.96, 2.47)	1.86 (1.17, 2.97)	1.88 (1.38, 2.54)	1.61 (1.16, 2.21)
ADLs	GS/BMI	2.22 (1.78, 2.75)	1.66 (1.32, 2.07)	2.52 (1.79–3.56)	1.67 (1.18, 2.37)	2.01 (1.50, 2.65)	1.59 (1.19, 2.13)
Instrumental	GS	4.32 (3.45, 5.40)	1.98 (1.25, 2.54)	7.18 (4.86, 10.6)	2.88 (1.83, 4.54)	3.03 (2.31, 3.99)	1.53 (1.13, 2.05)
ADLs	GS/BMI	3.47 (2.87, 4.19)	1.78 (1.44, 2.20)	4.27 (3.32, 6.67)	1.97 (1.43, 2.71)	3.13 (2.42, 4.03)	1.79 (0.34, 2.37)

Abbreviations: ADL, activities of daily living; BMI, body mass index; FNIH, Foundation for the National Institutes of Health; GS, grip strength; IADL, instrumental activities of daily living; PL, physical limitations. Odds ratios with 95% confidence intervals are presented. Models are weighted and adjusted for age, race, number of years of school, smoking status, comorbidities and physical activity status. Overall model also adjusts for sex. There were *n* = 3831 with nonpositive weights or weights = 0 that dropped out of the model. GS cutoffs: men, < 26 kg; women, < 16 kg; and GS/BMI: men, < 1.0; women, < 0.56. [a]Adjusted for age, race, number of years of schooling completed, smoking status, comorbidity and physical activity status.

Metabolic Syndrome.[18] Sixth, we defined physical limitations, basic ADL and instrumental ADL using composite scores in line with our previous analyses.[10] This could introduce bias in classifying limitations and affect our estimates observed in Table 4. Seventh, this population is a well-functioning, community-dwelling, older adult population that may not be typically representative of those in this age range. Eighth, there may be selection bias based on a survival effect in clinical studies in those over the age of 80 years may be relatively healthier. Last, we recognize that there were a number of participants we excluded, which could bias our results. However, an attempt was made to compare the characteristics of participants included and those excluded. The use of HRS respondent-level weights for the subanalysis (that contains adjustments for nonresponse) helped account for the potential bias (http://hrsonline.isr.umich.edu/modules/meta/tracker/desc/PMWeight2004_Description_public.pdf).

Although the thresholds focus on weakness and function, those with weakness and obesity were not adequately categorized. In the absence of body composition data, this cannot be determined using this data set. With over 35% of the older adult population having obesity,[19] the implications of muscle weakness in this subgroup should not be overlooked. In both cross-sectional[20] and longitudinal studies,[21] loss of muscle mass and weakness are associated with impairments in function. A major limitation of this current analysis is the inability to formally assess body fat and the inability to assess muscle mass, a core component of the sarcopenia definition.

Cutoff points are based and determined by their referent populations, all of which may have differing physical and functional characteristics. When applying different thresholds for a variable (that is, GS), altering a cutoff may markedly alter prevalence. Further, GS is a continuous variable and its relationship with impaired function, disability and mortality is based on this structure. Dichotomizing GS into low vs normal may affect those who are slightly above the threshold, yet their long-term risk may modestly be increased vs a counterpart just below this threshold. The potential for overdiagnosis (or underdiagnosis) of a clinical condition is possible.

To our knowledge, this is the first study to apply the FNIH criteria for weakness to the Health and Retirement Study. Although sarcopenia (and its components) is generally recognized in the geriatric literature, it is only increasingly being appreciated in the general medical community and in the primary care setting. Identification of individuals at risk for weakness allows for targeted interventions in the care setting and implementation of care planning for those at risk of frailty.[22] Our results suggest that irrespective of the definition used the association with impairment is evident. Recognition will allow prevention of the condition and its consequences, in addition to treatment of those with existing functional impairments. Only with standardized measures for identification will evaluation of proposed sets of outcomes,

including patient-reported outcomes, utilization and serious injury be performed. BMI is measured routinely in clinical settings, and integrating GS may be more practical and cost-effective than gait speed or other functional measures. However, future studies should determine the balance between diagnostic accuracy and practical incorporation in busy clinical practices.

CONFLICT OF INTEREST

ACKNOWLEDGEMENTS

AUTHOR CONTRIBUTIONS

JAB—conception, design, acquired data, analysis and interpretation, drafted the article, and final approval of the version to be published. CMG—conception, design, acquired data, analysis and interpretation, revised the article critically for important intellectual content, and final approval of the version to be published. EV—conception, design, acquired data, analysis and interpretation, revised article critically for important intellectual content, and final approval of the version to be published. SJB—analysis and interpretation, revised article critically for important intellectual content, and final approval of the version to be published.

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