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Original Study

Handgrip Weakness and Asymmetry Independently Predict the Development of New Activity Limitations: Results from Analyses of Longitudinal Data from the US Health and Retirement Study

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A B S T R A C T

Objectives: Examining strength asymmetries in assessments of muscle function may improve screenings for limitations in independent living tasks such as instrumental activities of daily living (IADL). We sought to determine the associations between handgrip strength (HGS) asymmetry and future IADL limitations in aging Americans.
Design: Longitudinal panel.
Setting and Participants: Secondary analyses of data from participants aged at least 50 years from the 2006-2016 waves of the Health and Retirement Study. The analytic sample included 18,235 Americans who identified hand dominance and had measures of HGS for both hands in a single wave.
Methods: Hand dominance was self-reported, and a handgrip dynamometer measured HGS on each hand. The highest HGS values on each hand were used to calculate the HGS asymmetry ratio: (nondominant HGS/dominant HGS). Individuals with HGS asymmetry ratio <0.80 or >1.20 had HGS asymmetry. Persons with HGS asymmetry ratio <0.80 had dominant HGS asymmetry, whereas participants with HGS asymmetry ratio >1.20 had nondominant HGS asymmetry. Persons with HGS asymmetry ratio <1.0 also had their ratio inversed to make all HGS asymmetry ratios ≥ 1.0. IADL were self-reported. Covariate-adjusted generalized estimating equations were used for the analyses.
Results: Participants with HGS asymmetry had 1.12 [95% confidence interval (CI): 1.03-1.20] greater odds for future IADL limitations. Each HGS asymmetry dominance group also had greater odds for future IADL limitations: 1.09 (CI: 1.01-1.18) for individuals with dominant HGS asymmetry and 1.29 (CI: 1.09-1.52) for persons with nondominant HGS asymmetry. Every 0.10 increase in inverted HGS asymmetry ratio was associated with 1.30 (CI: 1.07-1.57) greater odds for future IADL limitations.
Conclusions and Implications: Assessing HGS asymmetry, as another potential biomarker of impaired muscle function, may provide novel insights for predicting IADL limitations. Future research should continue examining how strength asymmetries, and other aspects of muscle function beyond maximal strength, factor into the disabling cascade.

Instrumental activities of daily living (IADL) are composed of neurophysiological-driven tasks that are necessary for independent living, and limitations in IADL are a precursor to cognitive impairment.[1] Physical measures that are often used for predicting declines in physical performance have emerged as a prognostic indicator for cognitive functioning.[2] Handgrip strength (HGS) is a convenient and ecologically valid assessment of overall strength capacity, and reliable measure of muscle function.[3,4] Low HGS has been shown to be independently and longitudinally associated with both IADL limitations and dementias in older adults.[5,6] Thus, measures of HGS have been

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recommended in routine geriatric health assessments for screening adverse health outcomes such as cognitive impairment.[7]

Although measures of HGS provide robust health information, maximal HGS alone could be an incomplete measure of muscle function.[8] Current HGS protocol guidelines focus exclusively on optimizing maximal grip force from a single hand regardless of dominance.[9] Although HGS measurements that are non-maximal are often overlooked,[9] such measures may provide additional information about how we assess muscle function and detect health conditions. For example, substantial bilateral differences in strength, operationalized by HGS asymmetry, have been shown to be robustly associated with low cognitive functioning and early all-cause mortality.[10,11] Therefore, adding diversity to assessments of muscle function may improve screening for age-related adverse health outcomes in clinical and research settings.

Continued research into the pathways that contribute to low muscle function and limitations in IADL are important because such factors represent the onset and progression of the disabling process.[12,13] Evaluating how HGS asymmetry is linked to IADL limitations could provide valuable insights into early identification and treatment for cognitive deficits. Such work may also help us better understand the motor change pathways that link physically driven measures, such as HGS, to neurophysiological tasks, such as IADL. This could, in turn, help the rapidly growing older adult population in the United States preserve their independence.[14] We sought to determine the associations between HGS asymmetry and future IADL limitations in aging Americans.

Methods

Participants

A secondary analysis of data from 18,683 Americans aged ≥50 years who had at least 1 wave of HGS measured with information about hand dominance (right, left), and 1 or more follow-up waves of IADL assessed in the 2006-2016 waves of the Health and Retirement Study (HRS) were analyzed for this investigation. The HRS is a longitudinal-panel study that observes health and economic factors during aging.[15] Participants engage in core interviews biennially until death. Interview response rates for the HRS have been >80%.[16] More details about the HRS are available elsewhere.[17]

Beginning in the 2006 wave, HRS data collections expanded to include enhanced face-to-face interviews with physical measures such as HGS and other biomarkers to provide greater depth for observing health factors.[16] To reduce participant burden, the enhanced face-to-face interviews alternated completion at each wave such that enhanced interviews were performed on half of the sample, whereas the other half sample only completed the core interview, usually by telephone. Participants provided written informed consent before entering the HRS, and the University's Behavioral Sciences Committee Institutional Review Board approved study protocols.

Measures

Instrumental activities of daily living

Ability to complete 6 IADL were reported at each wave: use a map, prepare hot meals, take medications, manage money, use a telephone, and shop for groceries. Respondents indicating an inability (ie, has difficulty with an IADL or cannot or does not do) in completing any IADL were considered as having an IADL limitaiton.[18,19] Likewise, respondents reporting an inability in completing a specific IADL were considered as having a limitation in that individual IADL.

Handgrip strength

A Smedley spring-type handgrip dynamometer (Scandidact; Odder, Denmark) measured HGS. Before beginning HGS testing, trained interviewers explained HGS protocols and fit the dynamometer to the hand size of each participant. A practice trial was completed with their arm positioned at the side and elbow flexed at 90°. After responding to the question "Which is your dominant hand?" participants squeezed the dynamometer with maximal effort starting on the nondominant hand. HGS was measured twice on each hand, alternating between hands. Persons unable to stand or position their arm while grasping the dynamometer could be seated and rest their upper arm on a supporting object during HGS testing.

Participants who had a surgical procedure in the previous 6 months, or swelling, inflammation, severe pain, or an injury to both hands in the previous month before the interview did not engage in HGS testing. More details about how HGS was measured in the HRS are published elsewhere.[20] The single greatest HGS value recorded from either hand was used for determining weakness. Men and women with maximal HGS <26 kg and <16 kg were considered weak, respectively.[21]

The greatest HGS values from the nondominant and dominant hands were used to calculate the HGS asymmetry ratio: [nondominant HGS (kilograms)/dominant HGS (kilograms)]. Given that limitations in IADL are a precursor for cognitive declines, previously published cut points for HGS asymmetry and cognitive functioning of a 20% difference in HGS between hands were used for our study.[10] Specifically, individuals with HGS asymmetry ratio <0.80 or >1.20 (ie, 20%) were considered as having any HGS asymmetry. Further, to identify dominance of HGS asymmetry, persons with HGS asymmetry ratio <0.80 were considered as having dominant HGS asymmetry, whereas individuals with HGS asymmetry ratio >1.20 were classified as having nondominant HGS asymmetry. The quotient was also calculated for persons with HGS asymmetry ratio <1.0 [(1/any HGS asymmetry ratio <1.0) inversed HGS asymmetry ratio] to make all HGS asymmetry ratios ≥1.0 (eg, HGS asymmetry ratio of 0.9 is equivalent to an inversed HGS asymmetry ratio of 1.1).

Covariates

At each wave, participants self-reported age, sex, race, educational achievement (not a high school graduate, high school graduate or passing equivalency exam with some college, college graduate or above), height, and body weight. Body mass index was calculated as height in meters divided by kilograms per meters-squared, and participants with a body mass index ≥30 were classified as obese. Respondents told interviewers if they were currently smoking cigarettes, and if they had ever smoked more than 100 cigarettes in their lifetime. Respondents also indicated if a health care provider had ever diagnosed them with hypertension, diabetes, cancer (excluding minor skin cancer), lung disease, heart condition, stroke, emotional or psychiatric problems, and arthritis. The number of affirmative morbid diagnoses were summed and included in the analyses. A single-item measure of self-rated health was collected wherein respondents perceived their health as "excellent," "very good," "good," "fair," or "poor."

Cognitive function was examined at each wave with the Telephone Interview of Cognitive Status, a well-validated screening tool from the Mini-Mental State Examination that was designed for population-based studies such as the HRS.[22] A 27-point composite scale was used for participants aged <65 years, which included immediate and delayed word recall from a list of 10 words, Serial Sevens Subtraction Test beginning with the number 100, and counting backward for 10 consecutive numbers at maximal speed starting from the number 20. Persons with scores <12 were considered as having a cognitive impairment.[23] Likewise, a 35-point scale was used for individuals aged ≥65 years that used 3 additional assessment items: object naming, date naming, and correctly identifying the current president and vice

president of the United States. Participants with scores <11 were classified as having a cognitive impairment.[24]

Depressive symptoms were evaluated with the Center for the Epidemiologic Studies Depression scale.[25] Respondents indicated if they experienced any negative (felt depressed, everything was an effort, restless sleep, loneliness, sadness, could not get going) or positive emotions (happiness, enjoyed life; reverse scored) during the week before the interview date. Scores ranged from 0 to 8, with higher scores suggesting more depressive symptoms. Participants with scores ≥3 were considered depressed.[25] Overall, there were n = 448 persons excluded for missing covariates (129 for IADL, 171 for obesity, 103 for smoking status, 31 for identified race, 7 for cognitive functioning, 4 for self-rated health, 2 for education, and 1 for health conditions).

Statistical analysis

All analyses were conducted with SAS 9.4 software (SAS Institute; Cary, NC). Participants entered our study when HGS was first measured. Current IADL limitation status and other covariates were examined at each wave in which HGS was collected (ie, every other wave). The outcome was IADL limitations at the next available wave. Supplementary Tables 1 and 2 show information about when participants first entered the study and when IADL were subsequently assessed. For most participants, IADL were assessed at the next wave of the HRS, but participants were also included for all waves in which they had HGS measured. The baseline descriptive characteristics of the participants were presented as mean ± standard deviation for continuous variables and frequency (percentage) for categorical variables. Independent *t* tests (continuous variables) and chi-squared tests (categorical variables) examined differences in the descriptive characteristics for persons with and without any HGS asymmetry.

Separate generalized estimating equations examined the associations of (1) HGS asymmetry (reference: HGS symmetry), (2) dominant and nondominant HGS asymmetry (reference: HGS symmetry), and (3) inverted HGS asymmetry ratio on future IADL limitations. Individual generalized estimating equations likewise analyzed the associations for each of the HGS asymmetry and weakness groups on future IADL limitations by age group (middle-aged: 50-64 years; older: ≥65 years) and sex. Further, distinct generalized estimating equations determined the associations for the HGS asymmetry and weakness groups on future individual limitations in a specific IADL. The models were adjusted for hand dominance, age, sex (when appropriate), obesity, educational achievement, cognitive impairment, self-rated health, morbid conditions, current smoking status, smoking history, depression, IADL limitation status at current wave, and time between waves.

Given that HGS asymmetry and weakness both came from measures of maximal HGS, individual generalized estimating equations determined if there was an interaction between weakness and (1) HGS asymmetry, (2) dominant and nondominant HGS asymmetry, and (3) inverted HGS asymmetry ratio for future IADL limitations. The results for the associations between HGS asymmetry and weakness on future IADL limitations from each generalized estimating equation would be presented independently if there was a nonsignificant interaction.

Further, receiver operating characteristic curve analyses were performed for inverted HGS asymmetry ratio and future IADL limitations. Youden *J*, which calculates the best combination of sensitivity and specificity (sensitivity + specificity − 1), was used to determine inverted HGS asymmetry ratio thresholds.[26,27] The findings from Youden *J* were considered supplementary because we were using previously published HGS asymmetry cut points a priori. An alpha level of 0.05 was used for all analyses.

Results

The analytic sample included 18,235 participants and their descriptive characteristics are listed in Table 1. Of these participants,

Table 1
Baseline Descriptive Characteristics of the Participants

Variables	Overall (n = 18,235)	Handgrip Strength Symmetry (n = 14,824)	Handgrip Strength Asymmetry (n = 3411)
Maximal handgrip strength, kg	32.6 ± 11.2	33.0 ± 11.2	30.6 ± 11.2*
Weakness, n (%)	984 (5.4)	716 (4.8)	268 (7.8)*
Age, y	64.9 ± 10.1	64.6 ± 10.0	66.3 ± 10.5*
Morbid conditions	1.8 ± 1.4	1.8 ± 1.3	2.1 ± 1.4*
Follow-up years	2.0 ± 0.5	2.0 ± 0.5	2.0 ± 0.5
Right hand dominant, n (%)	16,637 (91.2)	13,483 (90.9)	3154 (92.4)*
Cognitive impairment, n (%)	334 (1.8)	252 (1.7)	82 (2.4)
Male, n (%)	7717 (42.3)	6504 (43.8)	1213 (35.5)*
Obese, n (%)	3432 (35.2)	5155 (34.7)	1277 (37.4)*
Current smoker, n (%)	2826 (15.5)	2311 (15.5)	515 (15.1)
Previous smoker, n (%)	7473 (40.9)	6085 (41.0)	1388 (40.6)*
Self-rated health, n (%)			
Excellent	2006 (11.0)	1733 (11.7)	273 (8.0)*
Very good	5591 (30.7)	4692 (31.7)	899 (26.4)*
Good	5821 (31.9)	4691 (31.6)	1130 (33.1)
Fair	3688 (20.2)	2888 (19.5)	800 (23.4)*
Poor	1129 (6.2)	820 (5.5)	309 (9.1)*
Educational achievement, n (%)			
Not a HS graduate	3339 (18.3)	2638 (17.8)	701 (20.5)*
HS graduate or passing equivalent exam, some college	10,776 (59.1)	8768 (59.2)	2008 (58.9)
College graduate or above	4120 (22.6)	3418 (23.0)	702 (20.6)*
Depression, n (%)	3804 (20.8)	2966 (20.0)	838 (24.5)*
White race, n (%)	13,569 (74.4)	11,139 (75.1)	2430 (71.2)*
Duration in study, y	7.9 ± 2.5	7.9 ± 2.4	7.9 ± 2.5
IADL limitation at current wave, n (%)	5163 (28.3)	4011 (27.0)	1152 (33.7)*
IADL limitation at next wave, n (%)	5427 (29.7)	4196 (28.3)	1231 (36.0)*

HS, high school.
Characteristics are presented as mean ± standard deviation or frequency (percentage) where indicated.
*$P < .05$.

3411 (18.7%) had HGS asymmetry. Briefly, relative to individuals with HGS symmetry, persons with any HGS asymmetry had lower maximal HGS, and higher proportions of participants with weakness and IADL limitations at the current and next wave (all $P < .05$). The hand wherein weakness occurred by HGS asymmetry and future IADL limitation status is similarly presented in Supplementary Table 3.

Table 2 shows the results for the associations of HGS asymmetry and weakness on future IADL limitations. Asymmetric HGS ($P = .16$), dominant HGS asymmetry ($P = .10$), nondominant HGS asymmetry ($P = .56$), and inverted HGS asymmetry ratio ($P = .11$) did not interact with weakness. Each generalized estimating equation revealed that any HGS asymmetry, dominant HGS asymmetry, nondominant HGS asymmetry, and every 0.10 increase in inverted HGS asymmetry ratio was associated with 1.12 [95% confidence interval (CI): 1.03-1.20], 1.09 (CI: 1.01-1.18), 1.29 (CI: 1.09-1.52), and 1.30 (CI: 1.07-1.57) greater odds for future IADL limitations. Table 3 shows the results for the associations of HGS asymmetry and weakness on future IADL limitations by age group and sex. Men and middle-aged adults with any HGS asymmetry had 1.19 (CI: 1.05-1.36) and 1.20 (CI: 1.06-1.36) greater odds for future IADL limitations, respectively. Similarly, men with nondominant HGS asymmetry had 1.50 (CI: 1.17-1.93) greater odds for future IADL limitations, whereas middle-aged adults with dominant HGS asymmetry had 1.18 (CI: 1.03-1.36) greater odds for future IADL limitations.

Figure 1 depicts the proportions of individual IADL limitations by HGS asymmetry status. Table 4 shows the results for the associations of HGS asymmetry and weakness on future individual IADL limitations. Participants with any HGS asymmetry had 1.33 (CI: 1.14-1.56) greater odds for limitations in using a map. Further, persons with dominant HGS asymmetry had 1.36 (CI: 1.02-1.80) and 1.33 (CI: 1.12-1.57) greater odds for limitations in managing money and using a map, respectively. Every 0.10 increase in inverted HGS asymmetry ratio was also associated with 3.55 (CI: 1.02-12.40) greater odds for limitations in taking medications and 1.62 (CI: 1.09-2.42) greater odds for limitations in using a map. The results for the receiver operating characteristic curve analyses for the association between inverted HGS asymmetry ratio and future IADL limitations are presented in Supplementary Table 4. These analyses revealed an inverted HGS asymmetry ratio cut point of 1.2.

Table 2
Associations of Handgrip Strength Asymmetry and Weakness on Future Instrumental Activities of Daily Living Limitations

Explanatory Variables	Odds Ratio	95% Confidence Interval
Model 1		
Any handgrip strength asymmetry (n = 3411)*	1.12	1.03-1.20
Weakness (n = 984)†	1.61	1.42-1.82
Model 2		
Dominant handgrip strength asymmetry (n = 2772)*	1.09	1.01-1.18
Nondominant handgrip strength asymmetry (n = 639)*	1.29	1.09-1.52
Weakness (n = 984)†	1.60	1.41-1.81
Model 3		
Inverted handgrip strength asymmetry ratio (every 0.10 increase)	1.30	1.07-1.57
Weakness (n = 984)†	1.60	1.42-1.82

The models controlled for hand dominance, cognitive functioning, sex, morbid conditions, age, obesity, smoking status, self-rated health, depression, education, race, instrumental activities of daily living limitations at current wave, and time to follow-up.

*Reference: handgrip strength symmetry (n = 14,824).

†Reference: not weak (n = 17,251).

Table 3
Associations of Handgrip Strength Asymmetry and Weakness on Future Instrumental Activities of Daily Living Limitations by Age Group and Sex

Explanatory Variables	Odds Ratio	95% Confidence Interval
Any handgrip strength asymmetry		
Men		
Handgrip strength asymmetry*	1.19	1.05-1.36
Weakness†	1.62	1.33-1.97
Women		
Handgrip strength asymmetry*	1.08	0.98-1.18
Weakness†	1.62	1.38-1.90
Middle-aged adults		
Handgrip strength asymmetry*	1.20	1.06-1.36
Weakness†	1.59	1.16-2.17
Older adults		
Handgrip strength asymmetry*	1.06	0.96-1.16
Weakness†	1.50	1.31-1.72
Handgrip strength asymmetry dominance		
Men		
Dominant handgrip strength asymmetry*	1.12	0.97-1.29
Nondominant handgrip strength asymmetry*	1.50	1.17-1.93
Weakness†	1.59	1.31-1.94
Women		
Dominant handgrip strength asymmetry*	1.06	0.96-1.17
Nondominant handgrip strength asymmetry*	1.14	0.92-1.42
Weakness†	1.61	1.37-1.89
Middle-aged adults		
Dominant handgrip strength asymmetry*	1.18	1.03-1.36
Nondominant handgrip strength asymmetry*	1.25	0.96-1.63
Weakness†	1.58	1.15-2.15
Older adults		
Dominant handgrip strength asymmetry*	1.02	0.92-1.13
Nondominant handgrip strength asymmetry*	1.23	0.99-1.52
Weakness†	1.49	1.30-1.71

Each model was adjusted for hand dominance, cognitive functioning, sex (when appropriate), morbid conditions, age, obesity, smoking status, self-rated health, depression, education, race, time to follow-up, and instrumental activities of daily living limitations at current wave.

*Reference: handgrip strength asymmetry.

†Reference: not weak.

Discussion

The principal results of this investigation were that HGS asymmetry was differentially associated with future IADL limitations in aging Americans. Specifically, any HGS asymmetry was associated with 12% greater odds for future IADL limitations. Moreover, dominant and nondominant HGS asymmetry were associated with 9% and 29% greater odds for future IADL limitations, respectively. Every 10% increase in inverted HGS asymmetry ratio was likewise associated with 30% greater odds for future IADL limitations. Asymmetric HGS was differentially associated with future IADL limitations for each age group and sex. Further, HGS asymmetry was differentially associated with future limitations in individual IADL. These findings suggest that HGS asymmetry could help to predict future IADL limitations. Health care providers should consider assessments of HGS asymmetry, alongside other physical measures, in routine geriatric health assessments.

Hand dominance is reflective of brain hemisphere dominance,[28] and deficits in cognitive functioning in a brain hemisphere could be identified by shifts in hand laterality. For example, changes in lateralization between brain hemispheres in persons with declining cognitive functioning could be credited to the compensation of losses that are occurring in a brain hemisphere due to cognitive dysfunction.[29] Having wide differences in HGS between hands may reflect lower functioning in a brain hemisphere. This may help to explain our

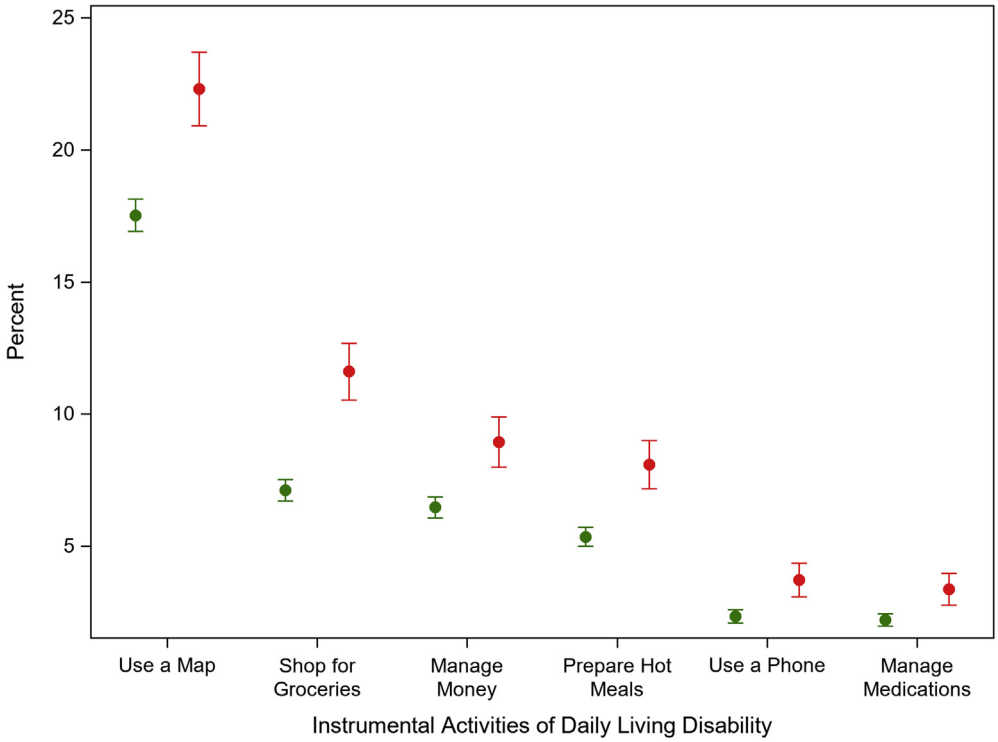

Fig. 1. Proportions of individual instrumental activities of daily living limitations by handgrip strength asymmetry status. Note: Results are presented as percentage and 95% confidence interval. Green: handgrip strength symmetry; Red: handgrip strength asymmetry.

findings for the association between HGS asymmetry and IADL limitations.

Changes in HGS are associated with each domain of cognitive functioning.[30] Autonomous-living tasks, such as IADL, similarly involve multiple aspects of neurophysiological function. For example, attention skills are needed to complete "first impact" IADL such as taking medications and managing money.[1,31] Spatial awareness skills are important for using a map.[32] Gender norms, and how such norms have changed over time, may have contributed to our findings for the association between HGS asymmetry and future IADL limitations by sex.[33] Future research examining how deficits in muscle function, including HGS asymmetry, could be associated with the neurophysiological aspects of IADL may provide insights into the body system pathways that contribute to unsuccessful aging.

The differences in the odds ratios for the associations between HGS asymmetry and weakness on future IADL limitations could be attributed to the crude proportions of participants living with HGS asymmetry or weakness, and if they experienced future IADL limitations (eg, sensitivity and specificity). Thus, HGS asymmetry could signify impaired muscle function that occurs before weakness. It is also possible that HGS asymmetry could be a less useful assessment of muscle function relative to weakness for future IADL limitations. Nevertheless, more research is needed for determining how HGS asymmetry and weakness are different, including how the HGS of each individual hand factors into weakness and HGS asymmetry, and their underlying motor change pathways that may lead to health complications during aging. Generating robust HGS asymmetry cut points may also provide more clarity with respect to HGS asymmetry and health, and improve interpretation for the use of HGS asymmetry in clinical and research settings.

Although some have suggested that HGS is a poor indicator of overall strength,[34,35] Bohannon[36] suggests that HGS is similarly

Table 4
Associations of Handgrip Strength Asymmetry and Weakness on Future Individual Limitations in Instrumental Activities of Daily Living

	Use a Map	Shop for Groceries	Manage Money	Prepare Hot Meals	Use a Telephone	Take Medications
Model 1						
Any HGS asymmetry (n = 3411)*	1.33 (1.14-1.56)	1.26 (0.98-1.62)	1.27 (0.98-1.65)	1.34 (0.99-1.82)	1.33 (0.81-2.18)	1.52 (0.90-2.56)
Weakness (n = 984)†	1.60 (1.25-2.05)	1.71 (1.19-2.46)	1.54 (1.06-2.24)	2.07 (1.37-3.13)	1.35 (0.70-2.62)	1.90 (0.92-3.96)
Model 2						
Dominant HGS asymmetry (n = 2772)*	1.33 (1.12-1.57)	1.20 (0.91-1.58)	1.36 (1.02-1.80)	1.25 (0.89-1.74)	1.31 (0.78-2.21)	1.59 (0.88-2.87)
Nondominant HGS asymmetry (n = 639)*	1.35 (0.96-1.89)	1.53 (0.89-2.62)	1.01 (0.60-1.70)	1.81 (0.94-3.48)	1.40 (0.49-4.00)	1.32 (0.54-3.21)
Weakness (n = 984)†	1.60 (1.25-2.04)	1.69 (1.18-2.43)	1.55 (1.07-2.26)	2.03 (1.34-3.08)	1.35 (0.69-2.62)	1.92 (0.92-3.97)
Model 3						
Inverted HGS asymmetry ratio (every 0.10 increase)	1.62 (1.09-2.42)	1.06 (0.69-1.64)	1.40 (0.79-2.47)	1.65 (0.82-3.32)	0.85 (0.41-1.78)	3.55 (1.02-12.40)
Weakness (n = 984)†	1.60 (1.25-2.04)	1.71 (1.19-2.46)	1.52 (1.04-2.22)	2.08 (1.38-3.14)	1.45 (0.74-2.83)	1.89 (0.90-3.95)

Results are presented as odds ratio (95% confidence interval). The models controlled for hand dominance, cognitive functioning, sex, morbid conditions, age, obesity, smoking status, self-rated health, depression, education, race, instrumental activities of daily living limitations at current wave, and time to follow-up.

*Reference: handgrip strength symmetry (n = 14,824).

†Reference: not weak (n = 17,251).

effective at measuring strength capacity in older adults relative to other modes, and could be preferred because of procedural ease. Measures of HGS asymmetry could be implemented immediately in current HGS protocol guidelines,[9] provide additional information for muscle function, maintain feasibility in measurement, and improve screenings for adverse health outcomes during aging. Thus, continued research should consider how HGS asymmetry contributes to the operationalization of muscle function, examine the associations of HGS asymmetry with other health conditions, and evaluate how HGS asymmetry factors into the disabling cascade.

Some of our study limitations should be acknowledged. Self-report information is common in population-based studies such as the HRS, but biases from self-report may have influenced our estimates. Similarly, self-reporting hand dominance may not have accurately captured shifts in hand dominance that could have occurred before or during our study period. The HRS uses a HGS protocol that differs from standardized HGS protocol guidelines so comparisons of findings across studies could be challenging.[9] Caution should be used when directly comparing the results of HGS asymmetry and weakness for future IADL limitations to one another because each group (HGS asymmetry; weakness) had a different reference. Most of our sample were white race and right hand dominant, so generalizability to nonwhite and left-handed persons was limited. Our analyses may have included multiple stratifications of certain variables, which in turn, could have influenced the confidence in some of our findings due to lower sampling. Participants must have had at least 2 waves of data to be included, and participants who may have been lost to follow-up after their first interview may have experienced accelerated declined in their muscle function and IADL capacity.

Conclusions and Implications

Our study found that HGS asymmetry was associated with future IADL limitations in aging Americans. We recommend that HGS asymmetry be considered alongside assessments of maximal HGS for improving the prognostic utility of handgrip dynamometers and better operationalizing muscle function. Future research should continue examining how HGS measurements outside of maximal strength are associated with prevalent health conditions in older populations. Such research may help to identify motor change pathways that contribute to age-related morbidity and disability. This could, in turn, help the rapidly growing older American population preserve independent living.

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Supplementary Table 1
Participant Flow for Wave in Which Handgrip Strength and Instrumental Activities of Daily Living were Assessed: First HGS Measured and Subsequent Instrumental Activities of Daily Living Assessed

A	Instrumental Activities of Daily Living Assessed				
	2008 Wave	2010 Wave	2012 Wave	2014 Wave	2016 Wave
First HGS measured					
2006 wave	6010	69	16	7	1
2008 wave	—	5285	79	26	4
2010 wave	—	—	2877	48	14
2012 wave	—	—	—	2831	72
2014 wave	—	—	—	—	896

HGS, handgrip strength.

Supplementary Table 2
Participant Flow for Wave in Which Handgrip Strength and Instrumental Activities of Daily Living were Assessed: All Waves Where HGS Was Measured and Subsequent Instrumental Activities of Daily Living Were Assessed

B	Instrumental Activities of Daily Living Assessed				
	2008 Wave	2010 Wave	2012 Wave	2014 Wave	2016 Wave
HGS measured					
2006 wave	6010	69	16	7	1
2008 wave	—	5285	79	26	4
2010 wave	—	—	6885	77	15
2012 wave	—	—	—	6380	103
2014 wave	—	—	—	—	5872

HGS, handgrip strength.

Supplementary Table 3
Hand Wherein Weakness Occurred by Handgrip Strength Asymmetry and Future Instrumental Activities of Daily Living Limitation Status

	HGS Symmetry and No Future IADL Limitation	HGS Symmetry and Future IADL Limitation	Any HGS Asymmetry and No Future IADL Limitation	Any HGS Asymmetry and Future IADL Limitation
Either hand not weak	10,105 (95.1)	3514 (83.8)	1634 (75.0)	617 (50.1)
Only right hand weak	63 (0.6)	73 (1.7)	99 (4.5)	109 (8.9)
Only left hand weak	178 (1.7)	175 (4.2)	347 (15.9)	337 (27.4)
Both hands weak	282 (2.6)	434 (10.3)	100 (4.6)	168 (13.6)

HGS, handgrip strength; IADL, instrumental activities of daily living.
Results are presented as frequency (percentage).

Supplementary Table 4
Results of the Receiver Operating Characteristic Curves for the Associations Between Inverted Handgrip Strength Asymmetry Ratio and Future Instrumental Activities of Daily Living Limitations

Variable	Cut Point	AUC	AUC 95% CI	Sensitivity (%)	Specificity (%)	OR	OR 95% CI
Inverted HGS asymmetry ratio	1.2	0.54	0.53-0.55	28.0	78.1	2.31	1.95-2.73

AUC, area under the curve; CI, confidence interval; HGS, handgrip strength; OR, odds ratio.