THE GERONTOLOGICAL SOCIETY OF AMERICA®

Journals of Gerontology: Medical Sciences
cite as: *J Gerontol A Biol Sci Med Sci*, 2020, Vol. XX, No. XX, 1–6
doi:10.1093/gerona/glaa100
Advance Access publication April 22, 2020

OXFORD

Research Practice

Handgrip Strength Asymmetry and Weakness Together Are Associated With Functional Disability in Aging Americans

Ryan McGrath, PhD,[1,*] Brenda M. Vincent, MS,[2] Donald A. Jurivich, DO,[3] Kyle J. Hackney, PhD,[1] Grant R. Tomkinson, PhD,[4,5] Lindsey J. Dahl, MD,[3] and Brian C. Clark, PhD[6,7]

[1]Department of Health, Nutrition, and Exercise Sciences, North Dakota State University, Fargo. [2]Department of Statistics, North Dakota State University, Fargo. [3]Department of Geriatrics, University of North Dakota, Grand Forks. [4]Department of Education, Health and Behavior Studies, University of North Dakota, Grand Forks. [5]Alliance for Research in Exercise, Nutrition and Activity, School of Health Sciences, University of South Australia, Adelaide, Australia. [6]Department of Biomedical Sciences, Ohio University, Athens. [7]Ohio Musculoskeletal and Neurological Institute, Ohio University, Athens.

*Address correspondence to: Ryan McGrath, PhD, Department of Health, Nutrition, and Exercise Sciences, North Dakota State University, Dept 2620, PO Box 6050, Fargo, ND 58108-6050. E-mail: ryan.mcgrath@ndsu.edu

Received: November 19, 2019; Editorial Decision Date: April 12, 2020

Decision Editor: Anne Newman, MD, MPH

Abstract

Background: Evaluating handgrip strength (HGS) asymmetry may help to improve the prognostic value of HGS. This study sought to determine the associations of HGS asymmetry and weakness on future activities of daily living (ADL) disability in a national sample of aging Americans.

Methods: The analytic sample included 18,468 Americans aged ≥50 years from the 2006–2016 waves of the Health and Retirement Study. A handgrip dynamometer measured HGS. Those with HGS >10% stronger on either hand were considered as having any HGS asymmetry. Individuals with HGS >10% stronger on their dominant hand were considered as having dominant HGS asymmetry, while those with HGS >10% stronger on their nondominant hand were classified as having nondominant HGS asymmetry. Men with HGS <26 kg and women with HGS <16 kg were considered weak. ADLs were self-reported. Generalized estimating equations were used for analyses.

Results: Relative to those with symmetric HGS and no weakness, each HGS asymmetry and weakness group had increased odds for future ADL disability: 1.11 (95% confidence interval [CI]: 1.02–1.20) for any HGS asymmetry alone, 1.42 (CI: 1.16–1.74) for weakness alone, and 1.81 (CI: 1.52–2.16) for both any HGS asymmetry and weakness. Most weakness and HGS asymmetry dominance groups had increased odds for future ADL disability: 1.30 (CI: 1.13–1.50) for nondominant HGS asymmetry alone, 1.42 (CI: 1.16–1.74) for weakness alone, 1.72 (CI: 1.29–2.29) for both weakness and nondominant HGS asymmetry, and 1.86 (CI: 1.52–2.28) for both weakness and dominant HGS asymmetry.

Conclusions: HGS asymmetry and weakness together may increase the predictive utility of handgrip dynamometers.

Keywords: Biomarkers, Disablement process, Epidemiology, Functional performance

Handgrip strength (HGS) is a convenient assessment of overall strength capacity that is associated with a wide range of health conditions (1). Weakness, as measured by HGS, is also part of decision algorithms for determining sarcopenia and dynapenia (2,3) and is included in validated frailty assessments (4). Similarly, muscle strength is a subdomain of the intrinsic capacity construct (5). As such, measures of HGS are recommended for routine health assessments and considered clinically viable for determining weakness (6). Given the rich health information that HGS provides, measures of HGS are a powerful biomarker of aging and vital sign of health status (7).

Guidelines for standardizing HGS protocols have been provided in an effort to reduce internal threats to validity, develop uniformity in assessments, and enable comparisons of results across studies that measure HGS (8). Within these guidelines, it is recommended that hand dominance be reported, measures of HGS be performed multiple times on each hand, and the highest ascertained value from these measurements be included in the analyses as maximal HGS (8). Large, population-based studies that have measured HGS, such as the Health and Retirement Study (HRS), similarly record hand dominance and values from multiple measures of HGS (9). However,

© The Author(s) 2020. Published by Oxford University Press on behalf of The Gerontological Society of America.
All rights reserved. For permissions, please e-mail: journals.permissions@oup.com.

Downloaded from https://academic.oup.com/biomedgerontology/advance-article/doi/10.1093/gerona/glaa100/5823708 by University of North Dakota user on 16 December 2020

it is conventional in assessments of HGS to include the highest measured value on either hand in analyses (8), with hand dominance and nonmaximal HGS measurements typically being disregarded.

Although HGS may vary between each hand and depend on handiness, the "10% rule" suggests that the HGS of the dominant hand is generally 10% stronger than that of the nondominant hand (10). Muscle strength asymmetry is linked to functional deficits in older populations. For example, asymmetric knee extension strength was associated with slower gait speed, greater gait variability, and asymmetry at near maximal speeds in a cross-sectional study of 24 older women (11). Nakao and colleagues (12) showed that increased knee extensor strength asymmetry and decreased absolute knee extensor strength was associated with poorer gait ability in a cross-sectional investigation of 30 older women. Another cross-sectional study of 20 older women found that asymmetric lower limb explosive power was larger in fallers than nonfallers (13). Given that asymmetric knee extensor strength may help to predict declines in function and mobility, it is also possible that HGS asymmetry may factor into future functional deficits in aging populations.

The use of HGS and knee extensor strength together has been recommended as a better measure of muscle strength than HGS alone (14); however, Bohannon (15) suggests that HGS and knee extension strength share a common construct (maximal limb muscle strength), and HGS is preferred because it is easier to measure. Examining HGS asymmetry, in combination with maximal HGS, may improve assessments of strength capacity by introducing a new construct (strength imbalance) that helps to ameliorate the limitations of performing dynamometry at a single site on the body (3,14). Moreover, evaluating HGS asymmetry still preserves the feasibility of HGS assessments because they are already part of HGS protocol guidelines (8). Yet, the role of HGS asymmetry in assessments of strength capacity is not well understood, nor has HGS asymmetry been shown to be associated with health conditions that are connected to low muscle strength. For example, maximal HGS is robustly associated with activities of daily living (ADL) (16,17) and recommended for inclusion–exclusion criteria, baseline evaluations, and end-point assessments for studies evaluating muscle function (18). Thus, examining HGS asymmetry in combination with maximal HGS may help to improve assessments of strength capacity and predictions of future health conditions in older adults such as functional disability. The purpose of this study was to determine the associations of HGS asymmetry and weakness on future ADL disability in a national sample of aging Americans.

Methods

Participants

Data from 18,810 Americans aged ≥50 and older who had at least one wave of HGS measured with information about hand dominance (right, left), and one or more follow-up waves of ADL assessed in the 2006–2016 waves of the HRS were analyzed for this investigation. The HRS is a panel study that monitors health and economic factors in aging Americans (19). New cohorts of participants are introduced to the HRS and interviewed biennially until death (20). More details about the HRS are available elsewhere (20).

Beginning in the 2006 wave, data collections in the HRS expanded to include face-to-face interviews with physical measures such as HGS and biomarkers to provide greater health-related depth. To minimize participant burden, the enhanced face-to-face interviews alternated completion at each wave, wherein enhanced interviews were performed on half of the sample, while the other half sample only completed the core interview (19). Response rates for the HRS have been >80% (19). Participants provided written informed consent before entering the HRS and the University's Behavioral Sciences Committee Institutional Review Board approved study protocols.

Measures

Functional disability

Ability to complete six ADLs was reported at each wave: dressing, eating, transferring in or out of bed, toileting, bathing, and walking across a small room. Those indicating difficulty or an inability to complete an ADL were considered as having an ADL disability.

Weakness

A Smedley spring-type handgrip dynamometer (Scandidact; Odder, Denmark) measured HGS. Before testing, interviewers explained HGS protocols and fit the dynamometer to the hand size of each participant before they performed a practice trial with their arm at the side and elbow flexed at a 90-degree angle. Participants responded to the question, "which is your dominant hand?" before HGS testing, and beginning on the nondominant hand, participants squeezed the dynamometer with maximal effort. Two measures were completed on each hand, alternating between hands. Those 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 last 6 months, or swelling, inflammation, severe pain, or an injury to both hands in the previous month before the interview did not engage in testing. More details about HGS testing in the HRS are published elsewhere (9). The single greatest HGS value recorded from either hand was used for determining weakness. Men with maximal HGS <26 kg and women with maximal HGS <16 kg were considered weak (21).

HGS asymmetry

The highest recorded HGS values from the nondominant and dominant hand were used to calculate the HGS ratio *(nondominant HGS (kg) / dominant HGS (kg))*. The "10% rule" guided how we determined HGS asymmetry, wherein participants who had an HGS ratio <0.90 (ie, 10%) were considered as having asymmetric dominant HGS, and those that had an HGS ratio >1.10 (ie, 10%) were classified as having asymmetric nondominant HGS (10). Moreover, those with either dominant or nondominant HGS asymmetry were also considered as having any HGS asymmetry.

Covariates

Respondents told interviewers their age, sex, race and ethnicity, height, and body mass at each wave. Those with obesity had a body mass index ≥30 kg per meters-squared. Morbidities were collected by self-reported health care provider diagnosed hypertension, diabetes, cancer (excluding minor skin cancer), lung disease such as bronchitis or emphysema, heart condition, stroke, emotional or psychiatric problems, and arthritis or rheumatism. The number of affirmative morbid diagnoses were summed at each wave and included in the analyses. Those who engaged in moderate-to-vigorous physical activity "one a week" or more were considered as participating in moderate-to-vigorous physical activity. Respondents reported their educational achievement and were categorized as either not graduating from high school, graduating from high school or passing a high school equivalency examination and completed some college, or a college graduate or above. Respondents also indicated if they

Downloaded from https://academic.oup.com/biomedgerontology/advance-article/doi/10.1093/gerona/glaa100/5823708 by University of North Dakota user on 16 December 2020

had ever smoked more than 100 cigarettes in their lifetime and if they were currently smoking cigarettes. Furthermore, a single-item measure of self-rated health was collected at each wave, whereby respondents perceived their health as either "excellent," "very good," "good," "fair," or "poor."

Social engagement was assessed by three variables at each wave: (i) volunteer activities at religious, education, health-related, or other organizations for at least one hour in the past year, (ii) at least weekly contact with parents or in-laws, and (iii) current employment status. Scores ranged from 0 to 3, with higher scores suggesting more social engagement. The continuous scores were included in the analyses (22).

Depressive symptoms were evaluated using the 8-item Center for the Epidemiologic Studies Depression scale (23). Respondents indicated if they experienced any negative or positive emotions during the week before the interview date. Scores ranged from 0 to 8, with higher scores suggesting more depressive symptoms. Those with scores ≥3 were considered as depressed (23).

Cognitive function was assessed in each wave by the Telephone Interview of Cognitive Status, a validated screening tool from the Mini-Mental State Examination that was designed for population-based studies (24). A 27-point composite scale was used for those under 65 years of age, and those with scores <12 were considered as having a cognitive impairment (25). A 35-point scale was used for those aged at least 65 years that used three additional assessment items, and persons with scores <11 were considered as having a cognitive impairment (26). Participants with missing or implausible covariates (eg, HGS >100 kg) were excluded (n = 342).

Statistical Analyses

All analyses were conducted with SAS 9.4 software (SAS Institute; Cary, NC). Participants entered our study when HGS was first measured. Current ADL disability status and other covariates were assessed at each wave in which HGS was collected. The outcome was ADL disability at the next available wave. Time to follow-up between waves in which HGS was measured, and the outcome was adjusted for in the analyses. Supplementary Appendix 1A provides a breakdown for when participants first entered our study and when ADLs were subsequently assessed. For most participants, ADL status was determined at the next wave of the HRS, such that time-to-follow-up was approximately 2 years. Participants were included for all waves in which they had HGS measured (Supplementary Appendix 1B). The descriptive characteristics of the participants are presented as mean ± standard deviation for continuous variables or frequency and percentage for categorical variables. Means and 95% confidence intervals (CI) for the descriptive characteristics of the participants were also presented to allow for comparisons between HGS asymmetry groups.

To examine how weakness and any HGS asymmetry interacted, separate generalized estimating equations (GEE) were performed for the associations with future ADL disability. The GEEs examined the associations of (i) weakness alone on future ADL disability (reference: not-weak; Model 1), (ii) any HGS asymmetry alone on future ADL disability (reference: symmetric HGS; Model 2), (iii) weakness alone (reference: not-weak) and any HGS asymmetry alone (reference: symmetric HGS) on future ADL disability (Model 3), and (iv) each weakness and any HGS asymmetry group (reference: both symmetric HGS and not-weak) on future ADL disability (Model 4). The findings from the GEE that determined the associations of each weakness and any HGS asymmetry group on future ADL disability were considered our principal results (ie, Model 4).

To examine how weakness and HGS asymmetry dominance interacted, these four GEEs were performed again after further classifying any HGS asymmetry into HGS asymmetry dominance (symmetric HGS, dominant HGS asymmetry, nondominant HGS asymmetry). The findings from the GEE that determined the association of each weakness and HGS asymmetry dominance group on future ADL disability were also considered our principal results (ie, Model 4).

As secondary analyses, separate GEEs examined the associations for each weakness and any HGS asymmetry group (reference: both symmetric HGS and not-weak) on future ADL disability stratified by (i) hand dominance (right-handed, left-handed), (ii) age group (aged 50–64 years, ≥65 years), and (iii) sex. Furthermore, separate GEEs determined the associations of each weakness and HGS asymmetry dominance group (reference: not-weak and symmetric HGS) on future ADL disability stratified by (i) hand dominance, (ii) age group, and (iii) sex. All GEEs were adjusted for ADL disability at current wave, age, sex, race and ethnicity, hand dominance, obesity, morbidities, moderate-to-vigorous physical activity participation, educational achievement, smoking history, current smoking status, self-rated health, social engagement, depression, cognitive functioning, and time between waves. For all GEEs, repeated measures were accounted for and the outcome for the next wave participated was used. An alpha level of 0.05 was used for all analyses.

Results

The descriptive characteristics of the 18,468 participants are given in Supplementary Table 1. Of these participants, 8,920 (48.3%) had symmetric HGS, 9,548 (51.7%) had any HGS asymmetry, 7,983 (43.2%) had asymmetric dominant HGS, and 1,565 (8.5%) had asymmetric nondominant HGS. The means and 95% CI for the descriptive characteristics are given in Supplementary Appendix 2. Maximal HGS (kg) was significantly lower in those with asymmetric nondominant (29.9; CI: 29.4–30.5) and dominant HGS (32.4; CI: 32.2–32.7) compared with those with symmetric HGS (33.3; CI: 33.1–33.6). Supplementary Appendix 3 displays a histogram for the differences in HGS between the dominant and nondominant hands.

Table 1 presents the results for the lagged associations of any HGS asymmetry and weakness on future ADL disability. Relative to those who were not-weak and had symmetric HGS, each weakness

Table 1. Results for the Lagged Associations of Any Handgrip Strength Asymmetry and Weakness on Future Functional Disability

	Odds Ratio	95% Confidence Interval
Model 1		
Weakness only (n = 990)[†]	1.55	1.35–1.77
Model 2		
Asymmetric handgrip strength only (n = 9,548)[‡]	1.12	1.04–1.21
Model 3		
Weakness only (n = 990)[†]	1.54	1.35–1.76
Asymmetric handgrip strength only (n = 9,548)[‡]	1.12	1.04–1.21

Note: Each generalized estimating equation was adjusted for activities of daily living disability at current wave, age, sex, race and ethnicity, hand dominance, obesity, morbidities, moderate-to-vigorous physical activity participation, educational achievement, smoking history, current smoking status, self-rated health, social engagement, depression, cognitive functioning, and time between waves.

[a]Reference: not-weak (n = 17,478).

[b]Reference: symmetric handgrip strength (n = 8,920).

Downloaded from https://academic.oup.com/biomedgerontology/advance-article/doi/10.1093/gerona/glaa100/5823708 by University of North Dakota user on 16 December 2020

and any HGS asymmetry group had increased odds for future ADL disability: 1.11 (CI: 1.02–1.20) for any HGS asymmetry only, 1.42 (CI: 1.16–1.74) for weakness only, and 1.81 (CI: 1.52–2.16) for both weakness and any HGS asymmetry. These results are also depicted in Figure 1 (ie, Model 4). The interaction for these strength capacity metrics by time was not significant (p = .10). Supplementary Appendix 4 shows the results for the lagged associations of any HGS asymmetry and weakness on future ADL disability stratified by hand dominance, age group, and sex. Differential associations for future ADL disability existed for each any HGS asymmetry and weakness group after stratifying the analyses by hand dominance, age group, and sex.

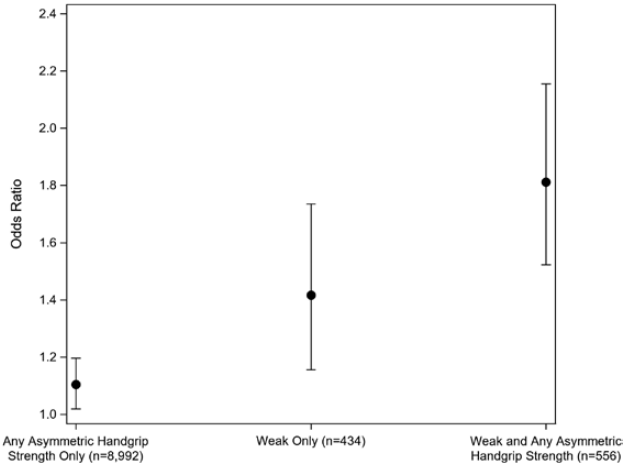

Figure 1. Results for the associations of any handgrip strength asymmetry and weakness and on future activities of daily living disability. *Note*: The symmetric handgrip strength and not-weak group was the reference (n = 8,486).

Table 2. Results for the Lagged Associations of Handgrip Strength Asymmetry Dominance and Weakness on Future Activities of Daily Living Disability

	Odds Ratio	95% Confidence Interval
Model 1		
Weakness only (n = 990)[a]	1.55	1.35–1.77
Model 2		
Asymmetric dominant handgrip strength only (n = 7,983)[b]	1.08	1.01–1.17
Asymmetric nondominant handgrip strength only (n = 1,565)[b]	1.31	1.16–1.50
Model 3		
Weakness only (n = 990)[a]	1.52	1.33–1.74
Asymmetric dominant handgrip strength only (n = 7,983)[b]	1.09	1.01–1.18
Asymmetric nondominant handgrip strength only (n = 1,565)[b]	1.28	1.12–1.45

Note: Each generalized estimating equation was adjusted for activities of daily living disability at current wave, age, sex, race and ethnicity, hand dominance, obesity, morbidities, moderate-to-vigorous physical activity participation, educational achievement, smoking history, current smoking status, self-rated health, social engagement, depression, cognitive functioning, and time between waves.

[a]Reference: not-weak (n = 17,478).

[b]Reference: symmetric handgrip strength (n = 8,920).

The results for the lagged associations of HGS asymmetry dominance and weakness on future ADL disability are given in Table 2. Compared with those who were not-weak and had symmetric HGS, most weakness and HGS asymmetry dominance groups had increased odds for future ADL disability: 1.30 (CI: 1.13–1.50) for nondominant HGS asymmetry only, 1.42 (CI: 1.16–1.74) for weakness only, 1.72 (CI: 1.29–2.29) for both weakness and nondominant HGS asymmetry, and 1.86 (CI: 1.52–2.28) for both weakness and dominant HGS asymmetry. There were null findings for the association of those with dominant HGS asymmetry only and future ADL disability (odds ratio: 1.07; CI: 0.98–1.16). Figure 2 also depicts these results (ie, Model 4). The interaction for these strength capacity metrics by time was not significant (p = .29). Supplementary Appendix 5 presents the results for the lagged associations of HGS asymmetry dominance and weakness on future ADL disability stratified by hand dominance, age group, and sex. Again, differential associations for future ADL disability existed for each HGS asymmetry dominance and weakness group after stratifying the analyses by hand dominance, age group, and sex.

Discussion

The principal results of this investigation revealed that HGS asymmetry and weakness were associated with future functional disability in a national sample of aging Americans. Specifically, those with HGS asymmetry alone had 11% increased odds for future ADL disability, persons with weakness alone had 42% increased odds for future ADL disability, and those with both any HGS asymmetry and weakness had 81% increased odds for future ADL disability. Moreover, those with both dominant HGS asymmetry and weakness had 86% increased odds for future ADL disability, and aging Americans with asymmetric nondominant HGS and weakness had 72% increased odds for future ADL disability. These findings suggest that combining assessments of HGS asymmetry with weakness may help to better predict future ADL disability and improve HGS as a screening tool for functional disability compared with maximal HGS measures alone.

While our findings support previous research that has found weakness is associated with functional disability in aging populations

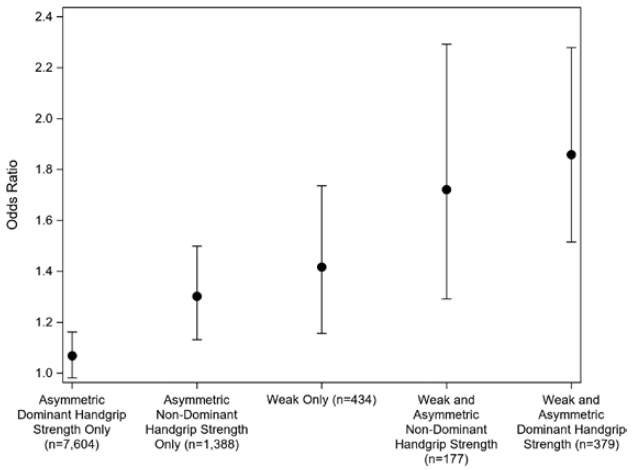

Figure 2. Results for the associations of handgrip strength asymmetry dominance and weakness on future activities of daily living disability. *Note*: The symmetric handgrip strength and not-weak group was the reference (n = 8,486).

Downloaded from https://academic.oup.com/biomedgerontology/advance-article/doi/10.1093/gerona/glaa100/5823708 by University of North Dakota user on 16 December 2020

(16), we also found that HGS asymmetry was associated with future ADL disability. HGS is intricately linked to the neural systems that mediate the control of coordinated movement, and declines in hand dexterity and maximal HGS are indicative of age-related muscle coordination deficits (27). Aging may also influence the functioning of the corpus callosum and interhemispheric communications that are responsible for bimanual coordination (28,29). Given that bimanual hand coordination is important for executing ADLs, deterioration of the nervous system during aging may have factored into poor bimanual hand coordination (30), which in turn, may help to explain why our findings showed HGS asymmetry was associated with future ADL disability in aging Americans. Although HGS asymmetry was associated with functional disability, the direction of the asymmetry may also provide valuable insights for ADL disability risk.

The amount of force produced during HGS measurements are generally stronger in the dominant hand (10), and the dominant hand often excels in motor performance tasks compared with the nondominant hand (31). As such, the nondominant hand, and side of the body, could be at risk for neuromuscular and musculoskeletal imbalances that may manifest into clinical issues (32). This may help to explain why both dominant HGS asymmetry and weakness were associated with functional disability in our study. Similarly, adults experience age-related changes in handiness due to overuse, hemispheric asymmetry, environmental factors, and use-dependent plasticity (33). Older adults may experience higher HGS in their nondominant hand relative to their dominant (34). Having higher HGS in the nondominant hand and body size asymmetry may also be an indicator for weakness (35,36). Each of these factors may help to explain why nondominant HGS asymmetry and weakness were also associated with future ADL disability. Health care providers should incorporate measures of HGS asymmetry in assessments of maximal strength capacity, communicate the potential health consequences of HGS asymmetry to their older patients, and converse strategies for not only improving weakness, but also strength balance. Older adults with both weakness and HGS asymmetry should especially be targeted for appropriate interventions to help preserve function.

Indeed, our findings revealed that weakness alone and any asymmetric HGS alone were associated with future functional disability in aging Americans. The odds ratios for future ADL disability increased in those who had both weakness and HGS asymmetry. We recommend that maximal HGS measurements on both hands and assessments of HGS asymmetry be considered in evaluations of strength capacity with handgrip dynamometers. Including such information in HGS protocols may help to improve the predictive utility of HGS for poor health outcomes. Furthermore, consideration for HGS asymmetry may refine consensus definitions of sarcopenia and dynapenia, and how functional performance is assessed (37,38). Future research should continue investigating HGS asymmetry with different experimental designs and analytical approaches, and how it is linked to other health conditions during aging. Refining HGS methods and technologies may also help to provide novel insights. Similarly, identifying effective strategies that not only help to retain muscle strength, but also symmetry in strength between limbs may better decelerate the disabling process.

Some limitations should be acknowledged. Participants must have had at least two waves of data to be included in the analyses, and those who may have been lost to follow-up after their first interview may have experienced rapid declines in their strength and functional capacity. Some findings from our secondary analyses could have been driven by smaller sample sizes in each group. Ambidextrous participants and those only able to complete HGS testing on one hand were excluded. Hand dominance was reported by participants without details regarding hand usage to complete tasks and reasons why hand dominance may have shifted. While the "10% rule" was used as the threshold for determining HGS asymmetry in our study, differences in HGS between hands may vary (39). Therefore, consideration should be given to asymmetry misclassifications for those near the 10% threshold at individual-levels. This provides opportunities for other studies to generate more precise HGS asymmetry cut points. Most of our sample were white race and right hand dominant, so the generalizability of our findings is limited with respect to nonwhite races and left-handed persons. Future research is needed to better generalize HGS asymmetry results to nonwhite races and left-handed individuals for their risk of future ADL disability.

Conclusions

We found that HGS asymmetry and weakness were associated with increased odds for future functional disability in a national sample of aging Americans. These findings suggest that HGS asymmetry, independently or in combination with assessments of weakness, could improve evaluations of muscle strength and the prediction of health conditions associated with strength capacity such as functional disability. Assessments of HGS asymmetry also preserve the cost-efficiency and feasibility of HGS because the dominant hand is recorded, and multiple measures of HGS are performed on each hand in most HGS test protocols.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

Funding

None reported.

Author Contributions

R.M. conceived and designed the study, participated in analyses, interpreted the results, and wrote the article; B.M.V. designed the study, participated in analyses, interpreted the results, and revised the article; D.A.J. designed the study, interpreted the results, and revised the article; K.J.H. designed the study, interpreted the results, and revised the article; G.R.T. designed the study interpreted the results, and revised the article; L.J.D. interpreted the results; B.C.C. designed the study, interpreted the results, and revised the article.

Conflict of Interest

None reported.

References

1. Bohannon RW. Muscle strength: clinical and prognostic value of hand-grip dynamometry. *Curr Opin Clin Nutr Metab Care*. 2015;18:465–470. doi:10.1097/MCO.0000000000000202
2. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. *Lancet*. 2019;393:2636–2646. doi:10.1016/S0140-6736(19)31138-9
3. Manini TM, Clark BC. Dynapenia and aging: an update. *J Gerontol A Biol Sci Med Sci*. 2012;67:28–40. doi:10.1093/gerona/glr010
4. Fried LP, Tangen CM, Walston J, et al.; Cardiovascular Health Study Collaborative Research Group. Frailty in older adults: evidence for

Downloaded from https://academic.oup.com/biomedgerontology/advance-article/doi/10.1093/gerona/glaa100/5823708 by University of North Dakota user on 16 December 2020

a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001;56:M146–M156. doi:10.1093/gerona/56.3.m146.
5. Cesari M, Araujo de Carvalho I, Amuthavalli Thiyagarajan J, et al. Evidence for the domains supporting the construct of intrinsic capacity. *J Gerontol A Biol Sci Med Sci*. 2018;73:1653–1660. doi:10.1093/gerona/gly011.
6. McGrath RP, Kraemer WJ, Snih SA, Peterson MD. Handgrip strength and health in aging adults. *Sports Med*. 2018;48:1993–2000. doi:10.1007/s40279-018-0952-y
7. Bohannon RW. Considerations and practical options for measuring muscle strength: a narrative review. *Biomed Res Int*. 2019;2019:8194537. doi:10.1155/2019/8194537
8. Roberts HC, Denison HJ, Martin HJ, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing*. 2011;40:423–429. doi:10.1093/ageing/afr051
9. Crimmins E, Guyer H, Langa K, Ofstedal M, Wallace R, Weir D. Documentation of physical measures, anthropometrics and blood pressure in the Health and Retirement Study. HRS Documentation Report. https://hrs.isr.umich.edu/sites/default/files/biblio/dr-011.pdf. Accessed November 19, 2019.
10. Armstrong CA, Oldham JA. A comparison of dominant and non-dominant hand strengths. *J Hand Surg Br*. 1999;24:421–425. doi:10.1054/jhsb.1999.0236
11. Laroche DP, Cook SB, Mackala K. Strength asymmetry increases gait asymmetry and variability in older women. *Med Sci Sports Exerc*. 2012;44:2172–2181. doi:10.1249/MSS.0b013e31825e1d31
12. Nakao H, Yoshikawa T, Mimura T, Hara T, Nishimoto K, Fujimoto S. Influence of lower-extremity muscle force, muscle mass and asymmetry in knee extension force on gait ability in community-dwelling elderly women. *J Phys Ther Sci*. 2006;18:73–79. doi:10.1589/jpts.18.73
13. Skelton DA, Kennedy J, Rutherford OM. Explosive power and asymmetry in leg muscle function in frequent fallers and non-fallers aged over 65. *Age Ageing*. 2002;31:119–125. doi:10.1093/ageing/31.2.119
14. Yeung SSY, Reijnierse EM, Trappenburg MC, Blauw GJ, Meskers CGM, Maier AB. Knee extension strength measurements should be considered as part of the comprehensive geriatric assessment. *BMC Geriatr*. 2018;18:130. doi:10.1186/s12877-018-0815-2
15. Bohannon RW. Are hand-grip and knee extension strength reflective of a common construct? *Percept Mot Skills*. 2012;114:514–518. doi:10.2466/03.26.PMS.114.2.514-518
16. Duchowny KA, Clarke PJ, Peterson MD. Muscle weakness and physical disability in older Americans: longitudinal findings from the U.S. health and retirement study. *J Nutr Health Aging*. 2018;22:501–507. doi:10.1007/s12603-017-0951-y
17. Germain CM, Vasquez E, Batsis JA, McQuoid DR. Sex, race and age differences in muscle strength and limitations in community dwelling older adults: data from the Health and Retirement Survey (HRS). *Arch Gerontol Geriatr*. 2016;65:98–103. doi:10.1016/j.archger.2016.03.007
18. Cesari M, Fielding RA, Pahor M, et al.; International Working Group on Sarcopenia. Biomarkers of sarcopenia in clinical trials—recommendations from the International Working Group on Sarcopenia. *J Cachexia Sarcopenia Muscle*. 2012;3:181–190. doi:10.1007/s13539-012-0078-2
19. Sonnega A, Faul JD, Ofstedal MB, Langa KM, Phillips JW, Weir DR. Cohort profile: the Health and Retirement Study (HRS). *Int J Epidemiol*. 2014;43:576–585. doi:10.1093/ije/dyu067
20. Health and Retirement Study. HRS Data Book. https://hrs.isr.umich.edu/about/data-book?_ga=2.177450149.1489958521.1509473800-353572931.1501594459. Accessed November 19, 2019.
21. Alley DE, Shardell MD, Peters KW, et al. Grip strength cutpoints for the identification of clinically relevant weakness. *J Gerontol A Biol Sci Med Sci*. 2014;69:559–566. doi:10.1093/gerona/glu011
22. Howrey B, Avila JC, Downer B, Wong R. Social Engagement and Cognitive Function of Older Adults in Mexico and the United States: How Universal is the Health Concordance in Couples? http://paa2019.populationassociation.org/uploads/191664. Accessed November 19, 2019.
23. Turvey CL, Wallace RB, Herzog R. A revised CES-D measure of depressive symptoms and a DSM-based measure of major depressive episodes in the elderly. *Int Psychogeriatr*. 1999;11:139–148. doi:10.1017/s1041610299005694.
24. Plassman BL, Newman TT, Welsh KA, Helms M, Breitner JC. Application in epidemiological and longitudinal studies. *Cogn Behav Neurol*. 1994;7:235–241.
25. Crimmins EM, Kim JK, Langa KM, Weir DR. Assessment of cognition using surveys and neuropsychological assessment: the Health and Retirement Study and the Aging, Demographics, and Memory Study. *J Gerontol B Psychol Sci Soc Sci*. 2011;66:i162–i171. doi:10.1093/geronb/gbr048
26. Langa KM, Larson EB, Karlawish JH, et al. Trends in the prevalence and mortality of cognitive impairment in the United States: is there evidence of a compression of cognitive morbidity? *Alzheimers Dement*. 2008;4:134–144. doi:10.1016/j.jalz.2008.01.001
27. Carson RG. Get a grip: individual variations in grip strength are a marker of brain health. *Neurobiol Aging*. 2018;71:189–222. doi:10.1016/j.neurobiolaging.2018.07.023
28. Fling BW, Walsh CM, Bangert AS, Reuter-Lorenz PA, Welsh RC, Seidler RD. Differential callosal contributions to bimanual control in young and older adults. *J Cogn Neurosci*. 2011;23:2171–2185. doi:10.1162/jocn.2010.21600
29. Hoy KE, Fitzgerald PB, Bradshaw JL, Armatas CA, Georgiou-Karistianis N. Investigating the cortical origins of motor overflow. *Brain Res Brain Res Rev*. 2004;46:315–327. doi:10.1016/j.brainresrev.2004.07.013
30. Shetty AK, Shankar MSV, Annamalai N. Bimanual coordination: influence of age and gender. *J Clin Diagn Res*. 2014;8:15–16. doi:10.7860/JCDR/2014/7333.3994
31. Noguchi T, Demura S, Nagasawa Y, Uchiyama M. An examination of practice and laterality effects on the Purdue Pegboard and Moving Beans with Tweezers. *Percept Mot Skills*. 2006;102:265–274. doi:10.2466/pms.102.1.265-274
32. Wallden M. Stimulus and response. *J Bodyw Mov Ther*. 2011;15:525–527. doi:10.1016/j.jbmt.2011.07.001
33. Sebastjan A, Skrzek A, Ignasiak Z, Sławińska T. Age-related changes in hand dominance and functional asymmetry in older adults. *PLoS One*. 2017;12:e0177845. doi:10.1371/journal.pone.0177845
34. Wang YC, Bohannon RW, Li X, Sindhu B, Kapellusch J. Hand-grip strength: normative reference values and equations for individuals 18 to 85 years of age residing in the United States. *J Orthop Sports Phys Ther*. 2018;48:685–693. doi:10.2519/jospt.2018.7851
35. Wang Y-C, Bohannon RW, Kapellusch J, et al. Between-side differences in hand-grip strength across the age span: findings from 2011–2014 NHANES and 2011 NIH Toolbox studies. *Laterality*. 2019;24:697–706. doi:10.1080/1357650x.2019.1604727
36. Fink B, Weege B, Manning JT, Trivers R. Body symmetry and physical strength in human males. *Am J Hum Biol*. 2014;26:697–700. doi:10.1002/ajhb.22584
37. Cawthon PM, Travison TG, Manini TM, et al. Establishing the link between lean mass and grip strength cut points with mobility disability and other health outcomes: proceedings of the Sarcopenia Definition and Outcomes Consortium Conference. *J Gerontol A Biol Sci Med Sci*. 2019. doi:10.1093/gerona/glz081
38. Mayhew AJ, Griffith LE, Gilsing A, Beauchamp MK, Kuspinar A, Raina P. The association between self-reported and performance-based physical function with activities of daily living disability in the Canadian Longitudinal Study on Aging. *J Gerontol A Biol Sci Med Sci*. 2020;75:147–154. doi:10.1093/gerona/glz122
39. Incel NA, Ceceli E, Durukan PB, Erdem HR, Yorgancioglu ZR. Grip strength: effect of hand dominance. *Singapore Med J*. 2002;43:234–237.

Downloaded from https://academic.oup.com/biomedgerontology/advance-article/doi/10.1093/gerona/glaa100/5823708 by University of North Dakota user on 16 December 2020