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Handgrip Strength Asymmetry is Associated with Slow Gait Speed and Poorer Standing Balance in Older Americans

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Handgrip Strength Asymmetry is Associated with Slow Gait Speed and Poorer Standing Balance in Older Americans

ABSTRACT

Introduction: Handgrip strength (HGS) asymmetry may help identify the functional asymmetries that contribute to mobility limitations. We sought to determine the associations of HGS asymmetry on gait speed and standing balance in older Americans.

Materials and Methods: The analytic sample included 8,396 adults aged ≥65-years for the last wave in which they participated in the 2006-2016 Health and Retirement Study. Participants were categorized into asymmetry groups based on the degree of HGS asymmetry. Persons with gait speed <0.8 meters/second were slow. Balance scores ranged from 0-4 with lower scores representing poorer standing balance.

Results: Older Americans with 20.1%-30.0% asymmetry had 1.22 (95% confidence interval (CI): 1.05-1.42) greater odds for slow gait speed, while those with >30.0% asymmetry had 1.23 (CI: 1.05-1.44) greater odds. Persons with 10.1%-20.0%, 20.1%-30.0%, and >30% asymmetry had 1.09 (CI: 1.07-1.22), 1.23 (CI: 1.07-1.42) and 1.40 (CI: 1.22-1.61) greater odds for poorer static balance, respectively. Those in each individual asymmetry group had greater odds for slow gait speed: 1.14 (CI: 1.03-1.26) for >10.0%, 1.19 (CI: 1.07-1.33) for >20.0%, and 1.16 (CI: 1.01-1.35) for >30.0%. Similar results were observed for poorer balance: 1.20 (CI: 1.09-1.32) for >10.0%, 1.27 (CI: 1.15-1.41) for >20.0%, and 1.31 (CI: 1.16-1.49) for >30.0%. Every 10% asymmetry increase was associated with 1.62 (CI: 1.32-1.99) greater odds for poorer balance.

Conclusions: The bimanual aspects of HGS asymmetry may reflect the bilateral movements required for mobility, and the relationship between upper and lower extremity strength and function may elucidate our findings.

Keywords: Aging; Geriatric Assessment; Geriatrics; Muscle Strength Dynamometer; Physical Functional Performance; Walking Speed

1.0 Introduction

Older adults experience several physiological and motor changes that increase their risk for age-related morbidity and disability (Tieland, Trouwborst, & Clark, 2018). Physical function assessments serve as a platform for observing these systematic changes (Bhasin et al., 2020). Declines in physical function generally occur progressively, with each subsequent stage of the disabling process representing greater impairment (Beaudart et al., 2019). Low handgrip strength (HGS) is an indicator of the muscle dysfunction that signifies the initial stages of the disabling process (Xue, 2011). Deficits in whole-body measures of physical performance, as identified by examining mobility-related tasks such as gait speed and standing balance, succeed impaired muscle function (Beaudart et al., 2019). The deficiencies that contribute to muscle dysfunction and poor physical performance lead to the restricted physical functioning that limits the capability to complete basic self-care tasks such as activities of daily living (Beaudart et al., 2019). Therefore, the use of physical function assessments in clinical settings can help to screen and monitor disablement risk, and allow for appropriate referrals that may decelerate losses in physical functioning (Patrizio et al., 2020).

Assessing muscle function could be particularly important for early detection of the disabling cascade because muscle dysfunction represents the onset of disablement (Beaudart et al., 2019; Xue, 2011). Low HGS is indeed a reliable marker of muscle dysfunction and powerful predictor of declining health (Cruz-Jentoft et al., 2018; McGrath et al., 2018). Measurement guidelines for maximal HGS recommend several trials be completed on each hand, with the highest recorded value, regardless of the hand, be used for determining strength capacity (Roberts et al., 2011). However, this method for determining strength capacity is unimanual and may not align well with the bilateral components involved in physical performance. For example, older adults with lower extremity strength asymmetries have greater gait variability (LaRoche et al., 2012), and the presence of such functional asymmetries may lead to overcompensation of the stronger limb during functional tasks (Bond et al., 2017). Given that upper and lower extremity strength are positively related (Bohannon, 2012), expanding HGS assessments to include measures from both hands may provide greater insights into the bilateral asymmetries that limit physical performance.

HGS asymmetry, as characterized by imbalances in HGS between hands, has emerged as a marker of muscle dysfunction that is also associated with several adverse health outcomes. For example, HGS asymmetry is associated with falls (McGrath et al., 2021a; Go et al., 2021), functional disability (Mahoney et al., 2022), and early all-cause mortality (McGrath et al., 2020b). While asymmetric HGS may signify a type of muscle dysfunction that precedes deficits in strength capacity (Mahoney et al., 2022), including HGS asymmetry assessments in muscle function screenings could be especially useful for evaluating the functional limb asymmetries that decrease physical functional performance. Early detection of these functional asymmetries at the muscle function level could prevent poor physical performance through referrals for interventions that are aimed at correcting such asymmetries. The purpose of this study was to determine the associations of HGS asymmetry on gait speed and standing balance in older Americans.

2.0 Methods

2.1 Participants

A secondary analysis of data from the Health and Retirement Study (HRS) was performed for this investigation. Individual HRS datafiles were joined to the cleaned and standardized RAND HRS dataset as appropriate (HRS Data Products). The HRS observes economic and health aspects in older Americans (Fisher & Ryan, 2017). Persons must be aged over 50 years to be eligible for the HRS, and new birth cohorts of participants are introduced to the HRS every six-years (HRS Data Book). Although individuals must be aged over 50 years to participate in the HRS, certain physical measures such as gait speed and standing balance are only collected from persons aged at least 65-years (Crimmins et al., 2008). Beginning in the 2006 wave of the HRS, detailed face-to-face interviews occurred for the collection of additional physical measurements (Fisher & Ryan, 2017). Trained HRS interviewers visited participant residences for these detailed interviews. The detailed interviews alternated completion at each wave of the HRS, wherein the physical measures were ascertained in a random half sample, and the other half sample engaged in core interviews, usually over the telephone (Sonnega et al., 2014). Interview response rates for each wave of the HRS were steadily >80% (Sonnega et al., 2014).

Our analytic sample included the last wave (cross-section) in which 11,369 Americans aged ≥65-years participated during the 2006-2016 waves of the HRS, with full information for gait speed, standing balance, and HGS on each hand. Complete information for these physical measures was part of our analytic sample inclusion criteria because each of these measurements has differing eligibility criteria in the HRS (Crimmins et al., 2008). Although the HRS utilizes a panel design, we analyzed the last wave in which older adults participated to best represent the most recent health-related measures recorded. The University's Behavioral Sciences Committee Institutional Review Board approved HRS protocols and all participants provided written informed consent prior to study entry. More details regarding the HRS are available elsewhere (HRS Data Book).

2.2 Measures

2.2.1 Gait Speed

Trained interviewers measured and created a walking course in an unobstructed and preferably non-carpeted area of the participants' residences. A piece of tape was put on the floor to identify the starting and ending points of the walking course. Pre-test instructions were provided. With their toes placed at the start line of the walking course, interviewers signaled when to begin walking by stating, "ready, begin" and participants walked at a normal pace, unassisted, across the 2.5-meter course. The interviewer started timing when the participant's foot was across the start line and completely touching the floor, and stopped timing when the participant's foot was similarly touching the floor beyond the finish line. After completion of the first walking trial, interviewers reset the stopwatch and advised participants to walk back to the other side of the walking course using the same protocol for the second trial. Walking aids were permitted if they were normally used for walking. Persons without sufficient space to conduct the test in their residence, and older adults with problems from a recent surgery, injury, or other health condition that prevented them from walking may not have engaged in gait speed testing (Crimmins et al., 2008). The mean of the two trials was calculated and persons with a mean gait speed <0.8 meters/second were considered slow (Cawthon et al., 2020). Additional details about the gait speed assessment in the HRS are available elsewhere (Crimmins et al., 2008).

2.2.2 Standing Balance

Interviewers located an area in participant residences where the floor was level with preferably no or low-pile carpet. Interviewers also examined the footwear of participants before testing their standing balance, and in some cases, participants were asked to remove or replace their shoes prior to testing. Each participant also discussed their ability to balance prior to the test. Participants who reported problems with balance resulting from a recent surgery, injury or condition were excluded from standing balance testing.

In the HRS, the semi-tandem (moderate-level) balance test was conducted first (Crimmins et al., 2008). Briefly, if participants were able to hold the semi-tandem position for 10 consecutive seconds without stepping out of position or grabbing the interviewer's arm then they were awarded a point for completing both the semi-tandem and side-by-side (lower-level) stands. Additionally, older adults who successfully completed the semi-tandem stand test were then asked to complete the full tandem position (advanced-level) under the same 10-second protocol. Persons that successfully held the full tandem position for 3-9 seconds were awarded another point, whereas individuals that held the position for the full 10-seconds received two points. However, participants who were unable to hold the semi-tandem (moderate-level) position for 10 consecutive seconds were instead asked to complete the side-by-side tandem stand (lower-level) under the same 10-second protocol. Individuals that maintained their balance for 10 consecutive seconds while in the side-by-side tandem stand were awarded a point. Participants were allowed to put either foot in front for the semi-tandem and full tandem positions. More details about the standing balance procedures in the HRS are available elsewhere (Crimmins et al., 2008). Scores ranged from 0-4 with lower scores suggesting poorer balance.

2.2.3 Handgrip Strength Asymmetry

A Smedley spring-type handgrip dynamometer (Scandidact; Odder, Denmark) was used to measure HGS. Trained interviewers fit the dynamometer to the hand size of participants and explained the HGS procedures. Each participant practiced gripping the dynamometer with their arm at their side and elbow flexed at 90°. Participants squeezed the dynamometer with maximal effort and then released their grip for two HGS trials on each hand, alternating between hands. Older adults who had problems standing or positioning their arm while grasping the dynamometer were allowed to be seated and place their arm on a supporting object during testing. Participants who experienced a surgical procedure within six months, or swelling, inflammation, severe pain, or an injury to their hands in the previous month before testing were excluded from participating in HGS testing. Additional details about the HGS protocols used in the HRS are available elsewhere (Crimmins et al., 2008).

The highest recorded HGS values from each hand were used to calculate HGS asymmetry. An asymmetry ratio was used to calculate the severity of asymmetry between the highest performing HGS measures regardless of hand: *(strongest HGS (kilograms) / strongest HGS on the other hand (kilograms))*. All asymmetry ratios where thus ≥1.0. Given that variability may exist in strength between hands, participants were categorized into groups based on the severity of their HGS asymmetry: 1) 0.0%-10.0%, 2) 10.1%-20.0%, 3) 20.1%-30.0%, and 4) >30.0% (Armstrong & Oldham, 1999; Incel et al., 2002; McGrath et al., 2020a; McGrath et al., 2021b).

2.2.4 Covariates

Participants reported their age, sex, race, height, and weight. Body mass index was calculated as weight in kilograms divided by height in meters-squared and persons with a body mass index of at least 30-kilograms per meters-squared were obese. The highest recorded HGS value from either hand was used to identify weakness for men and women as <35.0-kilograms and <20.0-kilograms, respectively (Cawthon et al., 2020). A single-item indicator of perceived health was reported as either “excellent”, “very good”, “good”, “fair”, or “poor”. Participants also self-reported if a healthcare provider had ever diagnosed them with hypertension, diabetes, cancer, lung disease, a heart condition, stroke, emotional or psychiatric problems, and arthritis. The number of affirmative diagnoses were summed and persons with at least two health conditions were considered as having multimorbidity. Respondents told interviewers if they had ever smoked more than 100 cigarettes in their lifetime (former smoker) and if they currently smoked cigarettes.

Cognitive functioning was examined with the 35-point adapted Telephone Interview of Cognitive Status (Plassman et al., 1994). This well-validated cognitive function screening tool is designed for population-based studies such as the HRS. Persons with scores ≤10 were considered as having a cognitive impairment (Langa et al., 2008). Individuals who reported engaging in moderate-to-vigorous physical activity at least "once a week" were considered as participating in moderate-to-vigorous physical activity. The 8-item Center for the Epidemiologic Studies Depression scale evaluated depressive symptoms (Turvey, Wallace, & Herzog, 1999). Respondents indicated if they experienced any positive or negative emotions during the week prior to the HRS interview. Scores ranged from 0-8, with higher scores suggesting more depressive symptomology, and persons with scores ≥3 were considered depressed (Turvey, Wallace, & Herzog, 1999). A data flow diagram that outlines exclusions is shown in Supplementary Figure 1.

2.3 Statistical Analysis

Analyses were conducted with SAS 9.4 software (SAS Institute; Cary, NC). The descriptive characteristics of the participants were presented as mean±standard deviation for continuous variables and frequency (percentage) for categorical variables overall and by HGS asymmetry group. To make comparisons between asymmetry groups, the descriptive characteristics were also presented as means and 95% confidence intervals (CI) as supplementary. A Pearson correlation quantified the relationship between HGS asymmetry ratio and maximal HGS. A crude and covariate-adjusted logistic regression model analyzed the associations of HGS asymmetry at 1) 10.1%-20.0%, 2) 20.1%-30.0%, and 3) >30.0% (reference: asymmetry 0.0%-10.0%) on slow gait speed. Likewise, a crude and covariate-adjusted ordered logit model quantified the associations between the same HGS asymmetry groups and poorer standing balance. Further, asymmetric HGS was then treated as a continuous variable (every 10.0% increase), and distinct crude and covariate-adjusted logistic and ordinal logit models determined the association of continuous HGS asymmetry on slow gait speed and poorer standing balance, respectively.

Separate crude and covariate-adjusted logistic models then examined the associations of the individual HGS asymmetry groups at 1) >10.0% (reference: 0.0%-10.0%), 2) >20.0% (reference: 0.0%-20.0%), and >30.0% (reference: 0.0%-30.0%) on slow gait speed. Similarly, separate crude and covariate-adjusted ordinal logistic models evaluated the associations between these individual HGS asymmetry groups and poorer standing balance. Moreover, gait speed was treated as a continuous variable, and crude and covariate-adjusted linear regression models analyzed the associations of the combined and individual groups, and continuous HGS asymmetry on continuous gait speed. The covariate-adjusted models controlled for age, sex, weakness, race, multimorbidity status, obesity status, self-rated health, social engagement, cognitive functioning, depressive status, moderate-to-vigorous physical activity participation, current smoking status, and smoking history. All covariates were pre-specified. The findings from the fully-adjusted models were presented as our primary results.

We also performed several supplementary analyses. To examine sex as a biological variable on our findings (NIH Office of Research on Women's Health), each of our covariate-adjusted regression models was stratified by sex. While cognitive functioning was an important covariate to control for in our principal analyses (Carson, 2018), we also excluded n=2,714 for missing information on cognitive function. Therefore, we removed cognitive functioning from our analyses and included an additional n=2,714 into our analytic sample for conducting the same regression analyses. We additionally conducted the same series of regression analyses with stroke as a stand-alone covariate (n=696; thereby subtracting a condition from our summed affirmative health condition variable) and transformed relevant binary covariates into continuous covariates. These additional analyses were presented as supplementary and were not discussed because they were not principal to our investigation. An alpha level of 0.05 was used for all analyses.

3.0 Results

The descriptive characteristics of the 8,396 older Americans included in our study are shown in Table 1. Overall, participants were aged 76.1±7.2 years and were predominantly female (n=4,705 (56.1%)). Supplementary Table 1 also shows the means and CI for the descriptive characteristics of the participants. More persons with HGS asymmetry >30.0% were slower (68.8% (CI: 66.2, 71.4)) compared to individuals with 0.0%-10.0% asymmetry (60.2% (CI: 58.6, 61.8). Figure 1 displays a scatter plot for maximal HGS and asymmetry ratio. A trivial, and negative correlation exists between HGS and asymmetry ratio (r=-0.06; p<0.0001).

Table 2 presents the results for the associations of the HGS asymmetry groups on gait speed and standing balance. Compared to those with asymmetry 0.0%-10.0%, older Americans with 20.1%-30.0% asymmetry had 1.22 (CI: 1.05, 1.42) greater odds for slow gait speed, while those with asymmetry >30.0% had 1.23 (CI: 1.05, 1.44) greater odds. Moreover, persons with HGS asymmetry at 10.1%-20.0%, 20.1%-30.0%, and >30.0% had 1.09 (CI: 1.07, 1.22), 1.23

(CI: 1.07, 1.42) and 1.40 (CI: 1.22, 1.61) greater odds for poorer standing balance, respectively. Each individual HGS asymmetry group had greater odds for slow gait speed: 1.14 (CI: 1.03, 1.26) for >10.0% asymmetry, 1.19 (CI: 1.07, 1.33) for >20% asymmetry, and 1.16 (CI: 1.01, 1.35) for >30% asymmetry. Every individual asymmetry group also had greater odds for poorer standing balance: 1.20 (CI: 1.09, 1.32) for >10.0% asymmetry, 1.27 (CI: 1.15, 1.41) for asymmetry >20.0%, and 1.31 (CI: 1.16, 1.49) for asymmetry >30.0%. Every 10% increase in continuous HGS asymmetry was associated with 1.62 (CI: 1.32, 1.99) greater odds for poorer standing balance.

Table 3 shows the results of each HGS asymmetry group on continuous gait speed. Relative to those with asymmetry 0.0%-10.0%, only persons with asymmetry >30% had decreased gait speed (β=-0.03; CI: -0.04, -0.02). Each individual HGS asymmetry group was similarly associated with decreased gait speed (β=-0.01, CI: -0.02, -0.01 for >10% asymmetry; β=-0.02, CI: -0.03, -0.01 for >20% asymmetry; β=-0.02, CI: -0.03, -0.01 for asymmetry >30.0%). Every 10.0% increase in continuous HGS asymmetry ratio was associated with decreased gait speed (β=-0.05; CI: -0.07, -0.03).

Supplementary Table 2 shows the results for the associations of the HGS asymmetry groups on gait speed and standing balance by sex, while Supplementary Table 3 presents the findings for the associations of each HGS asymmetry group on continuous gait speed by sex. Supplementary Table 4 shows results for the associations of the HGS asymmetry groups on gait speed and standing balance without cognitive functioning as a covariate, and Supplementary Table 5 presents findings for the associations of the HGS asymmetry groups on continuous gait speed again without cognitive function as a covariate. Supplementary Table 6 provides results for the associations of the HGS asymmetry groups on gait speed and standing balance with relevant continuous covariates in the models and stroke as a stand-alone covariate, and Supplementary Table 7 presents results for the same HGS asymmetry groups and covariate treatment on continuous gait speed.

4.0 Discussion

The principal findings of this investigation revealed that HGS asymmetry is associated with slow gait speed and poorer standing balance in older Americans. Specifically, when evaluating the combined HGS asymmetry groups, older Americans with 10.1-20.0% asymmetry had 9% greater odds for poorer standing balance. Persons with 20.1%-30.0% asymmetry had 22% greater odds for slow gait speed and 23% greater odds for poorer standing balance. Likewise, individuals with >30.0% asymmetry had 23% greater odds for slow gait speed and 40% greater odds for poorer standing balance. When individualizing the HGS asymmetry groups, older Americans were at 14% greater odds for slow gait speed with >10.0% asymmetry, 19% greater odds for slow gait speed with >20.0% asymmetry, and 16% greater odds for slow gait speed with >30.0% asymmetry. Similarly, persons with >10.0%, >20.0%, and >30.0% asymmetry had 20%, 27%, and 31% greater odds for poorer standing balance, respectively. Every 10% increase in HGS asymmetry was associated with 62% greater odds for poorer standing balance. HGS asymmetry was also associated with decreased gait speed. These findings indicate that HGS asymmetry, as another marker of impaired muscle function, may have prognostic value for detecting poor physical performance.

Our findings align with previous work that suggests between-limb lower extremity strength asymmetries are associated with functional capacity in older adults (Mertz et al., 2019). Others have shown that gait variability may occur in older adults with lower extremity functional asymmetries (LaRoche et al., 2012). Given that upper and lower extremity strength are related

(Bohannon, 2012), the lower extremity functional asymmetries that contribute to slow gait speed could be identified by HGS asymmetry. The magnitude of the associations between HGS asymmetry and slow gait speed observed in our study may have also increased if HRS participants completed a fast walking speed test instead of comfortable walking speed because such lower extremity functional asymmetries are more exposed when older adults walk near maximal capacities (LaRoche et al., 2012). As such, examining HGS asymmetry may reveal the same lower extremity functional asymmetries that factor into slower gait speed.

Standing balance is a marker of physical performance, and is linked to factors such as neuromuscular control (Dunsky, 2019; Patrizio et al., 2020). Poor standing balance is included in American fall risk screening recommendations for older adults (Stevens & Phelan, 2013). Functional asymmetries in the lower limbs are linked to poorer standing balance (Portegijs et al., 2005). Unlike other dynamic physical performance assessments such as gait speed, static-bilateral control is required for standing balance. HGS is an isometric grip force task that may relate to other isometric tasks such as standing balance. Indeed, a positive relationship exists between lower and upper extremity strength (Bohannon, 2012), and the same lower extremity isometric functional asymmetries that may be inhibiting standing balance could be identified by HGS asymmetry. Such functional asymmetries may help to explain why we found HGS asymmetry was associated with poorer standing balance in older Americans.

There could be several mechanisms that connect HGS asymmetry to physical performance. Lower extremity lean mass asymmetry is associated with poor physical performance (Lee et al., 2019), and the same muscle mass asymmetry could be occurring in the upper extremities. Although we controlled for cognitive functioning in our analysis, neurodegenerative disorders are that could be linked to HGS asymmetry advance insidiously at an asymptomatic stage (Chen et al., 2022). For example, Motoric Cognitive Risk Syndrome is a pre-dementia syndrome that is characterized by cognitive complaints and slow gait speed (Verghese et al., 2019). Given that HGS asymmetry occurs before weakness and may reflect brain hemisphere morbidity-related dysfunction (McGrath et al., 2020a), the presence of asymmetric HGS may represent the diminished neural system activities that influence poor physical performance. Further, environmental factors may impact hand usage and strength (Sebastjan et al., 2017). Acute and chronic (e.g., overuse) injuries may contribute to overcompensation and deficits in the mechanics needed for completing physical tasks. The several body systems and environmental factors that may underpin why HGS asymmetry is associated with poor physical performance warrant continued investigation into how we can improve our understanding of the underlying mechanisms of age-related motor changes for improving our muscle function assessments (McGrath et al., 2021c).

Our investigation presented another method for determining HGS asymmetry such that we calculated the quotient of the maximum HGS values for each hand. This asymmetry formula, for example, enables ambidextrous persons to be included and improves asymmetry ratio interpretation because all ratios will be ≥1.0. We also utilized different methods for examining HGS asymmetry, such that we created combined HGS asymmetry groups (0.0%-10.0%, 10.1%-20.0%, 20.1%-30.0%, >30.0%), individual HGS asymmetry groups (>10.0%, >20.0%, >30.0%), and continuous HGS asymmetry ratio. The decision to use different methods for defining HGS asymmetry reflects the different degrees of asymmetry severity observed by others (Armstrong & Oldham, 1999; Incel et al., 2002; McGrath et al., 2020a; McGrath et al., 2021b), while similarly presenting a moving cut-point for defining HGS asymmetry. Other work has factored in hand dominance for the creation of asymmetry ratio (Mahoney et al., 2022) and defined HGS asymmetry with percent difference equations (McGrath et al., 2021a). While no universal method for calculating and defining HGS asymmetry currently exists, until HGS asymmetry methods become more established, heterogeneity in HGS methods may exist across studies.

Examining lower extremity muscle function, especially in clinical settings, poses several challenges to both assessors and patients (Beaudart et al., 2019). Evaluating HGS asymmetry may provide a biomarker for identifying the functional asymmetries that contribute to poor physical performance and related adverse health outcomes (McGrath et al., 2021a). Accordingly, HGS asymmetry may characterize as another type of muscle function impairment (strength asymmetry). We suggest that HGS asymmetry be assessed alongside maximal strength in HGS protocols, especially because most HGS procedures are collecting measurements on both hands already (Roberts et al., 2011). Examining HGS asymmetry may help to diversify how we feasibly assess muscle function, improve screenings for physical function, and provide insights into the underlying physiological and motor system deficits that factor into age-related morbidity and disability. Given that cut-points for weakness are often anchored to physical performance assessments such as gait speed (Alley et al., 2014), the development of validated HGS asymmetry cut-points from preferably pooled data will help to create consistency for how asymmetric HGS is defined. Continuing to evaluate how HGS asymmetry factors into muscle function and the disabling process with longitudinal designs may advance muscle function assessments for preventing and slowing disablement.

4.1 Limitations

Some limitations should be acknowledged. Although other assessments of physical performance may exist, the inclusion of walking speed and standing balance for our study was based on HRS data availability and suggestions from the locomotion domain of intrinsic capacity framework (Cesari et al., 2018). Participants were allowed to choose their leading foot for the semi-tandem and full tandem balance positions, which may not have exposed cases of poorer balance. While HRS utilizes a longitudinal-panel design, we analyzed the last available wave in which persons participated in the HRS, which may explain why our sample was generally older and cases of asymmetry were higher. It is also probably that a larger proportion of our sample was frail given the descriptive characteristics. This decision was selected because the physical measures (HGS, walking speed, standing balance) were collected concurrently in each biennial detailed face-to-face interview with differential inclusion criteria. Thus, our ability to conduct longitudinal analyses was limited. We provided findings from a cross-sectional design, and future research examining HGS asymmetry and physical performance should utilize longitudinal designs to support or dispute our findings. Nonetheless, our modeling aligns with the process of muscle dysfunction occurring before poor physical performance (Beaudart et al., 2019). Stratifying asymmetry by direction of hand dominance led to imbalanced sample sizes. Our sample was predominantly white race so the generalizability of our findings may be limited.

5.0 Conclusions

This study revealed that HGS asymmetry was associated with slow gait speed and poorer standing balance in older Americans. We recommend that HGS asymmetry, as another marker of impaired muscle function, be used in clinical and translational research settings for more easily identifying the functional asymmetries that may contribute to poor physical performance. Using HGS asymmetry as a mode for screening functional asymmetries may also help with early referrals to appropriate interventions aimed at preventing or slowing the disabling process. Future research should continue examining how HGS asymmetry may diversify muscle function assessments for better operationalizing dysfunction and predicting poor physical performance.

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FIGURE LEGEND

Figure 1. Scatter Plot for Maximal Handgrip Strength and Asymmetry Ratio.

Note: n=12 validated and non-influential asymmetry ratios >3.0 were not displayed for figure resolution purposes. Green circle=95% prediction ellipse. Red line=correlation coefficient.

Supplementary Figure 1. Data Flow Diagram.

Note: BMI=body mass index, HRS=Health and Retirement Study, MVPA=moderate-to-vigorous physical activity.

Table 1. Descriptive Characteristics of the Participants.

	Overall (n=8,396)	HGS Asymmetry 0.0%-10.0% (n=3,531)	HGS Asymmetry 10.1%-20.0% (n=2,403)	HGS Asymmetry 20.1%-30.0% (n=1,246)	HGS Asymmetry >30.0% (n=1,216)
Age (years)	76.1±7.2	75.7±7.0	76.0±7.3	76.2±7.3	77.1±7.5
Young Old (n (%))	3,897 (46.4)	1,713 (48.5)	1,119 (46.5)	572 (45.9)	495 (40.7)
Maximal Handgrip Strength (kilograms)	28.0±9.9	28.3±10.0	28.6±9.9	28.1±9.7	26.2±9.6
Weakness (n (%))	3,456 (41.2)	1,530 (43.3)	930 (38.7)	464 (37.2)	533 (43.8)
Female (n (%))	4,705 (56.1)	1,861 (52.7)	1,324 (55.1)	749 (60.1)	772 (63.5)
White Race (n (%))	7,037 (83.8)	2,989 (84.7)	2,009 (83.6)	1,043 (83.7)	997 (82.0)
Body Mass Index (kg/m^2)	27.5±5.5	27.5±5.3	27.5±5.7	27.6±5.7	27.4±5.8
Obesity (n (%))	2,343 (27.9)	1,001 (28.4)	666 (27.7)	322 (26.7)	344 (28.3)
Health Conditions	2.6±1.4	2.5±1.4	2.6±1.4	2.6±1.5	2.7±1.4
Multimorbidity (n (%))	6,398 (76.2)	2,659 (75.3)	1,835 (76.4)	954 (76.6)	951 (78.2)
TICS Score	20.8±5.1	21.0±5.1	20.8±5.1	20.9±5.1	20.4±5.2
Cognitive Impairment (n (%))	324 (3.9)	130 (3.7)	97 (4.0)	48 (3.9)	49 (4.0)
Fair or Poor Perceived Health (n (%))	2,526 (30.1)	1,010 (28.6)	758 (31.6)	380 (30.5)	379 (31.2)
CES-D Score	1.3±1.8	1.3±1.8	1.4±1.9	1.2±1.8	1.4±1.9
Depression (n (%))	1,003 (12.0)	405 (11.5)	306 (12.7)	143 (11.5)	149 (12.3)
Social Engagement	1.1±0.8	1.1±0.8	1.1±0.8	1.1±0.8	1.0±0.8
Current Smoker (n (%))	811 (9.7)	349 (9.9)	248 (10.3)	113 (9.1)	102 (8.4)
Never Smoked (n (%))	3,546 (42.2)	1,449 (41.1)	989 (41.2)	553 (44.4)	555 (45.6)
MVPA Participation (n (%))	4,218 (50.3)	1,821 (51.6)	1,183 (49.3)	640 (51.4)	574 (47.2)
Gait Speed (m/s)	0.73±0.24	0.75±0.24	0.73±0.25	0.73±0.24	0.69±0.23
Slow Gait Speed (n (%))	5,274 (62.8)	2,126 (60.2)	1,500 (62.4)	813 (65.3)	837 (68.8)
Balance Score (n (%))					
0	27 (0.3)	10 (0.3)	7 (0.3)	2 (0.2)	8 (0.7)
1	708 (8.5)	260 (7.4)	204 (8.5)	115 (9.2)	129 (10.6)
2	1,009 (12.0)	385 (10.9)	283 (11.8)	153 (12.3)	188 (15.4)
3	1,008 (12.0)	408 (11.5)	267 (11.1)	165 (13.2)	168 (13.8)
4	5,644 (67.2)	2,468 (69.9)	1,642 (68.3)	811 (65.1)	723 (59.5)

Note: Results are presented as mean±standard deviation or frequency (percentage) where indicated. CED-D=center for the epidemiologic studies-depression, HGS=handgrip strength, kg/m^2=kilograms per meters-squared, m/s=meters per second, MVPA=moderate-to-vigorous physical activity, TICS=telephone interview of cognitive status, Young Old=aged 65-74 years.

Table 2. Results for the Associations of the Handgrip Strength Asymmetry Groups on Gait Speed and Standing Balance.

	Crude Models		Fully-Adjusted Models	
	Odds Ratio	**95% Confidence Interval**	**Odds Ratio**	**95% Confidence Interval**
Combined HGS Asymmetry Groups†				
Slow Gait Speed				
HGS Asymmetry 10.1%-20.0% (n=2,403)	1.10	0.99, 1.22	1.06	0.94, 1.20
HGS Asymmetry 20.1%-30.0% (n=1,246)	1.24	1.09, 1.42	1.22	1.05, 1.42
HGS Asymmetry >30.0% (n=1,216)	1.46	1.27, 1.68	1.23	1.05, 1.44
Poorer Standing Balance				
HGS Asymmetry 10.1%-20.0% (n=2,403)	1.09	0.98, 1.22	1.09	1.07, 1.22
HGS Asymmetry 20.1%-30.0% (n=1,246)	1.24	1.08, 1.42	1.23	1.07, 1.42
HGS Asymmetry >30.0% (n=1,216)	1.58	1.39, 1.80	1.40	1.22, 1.61
Individual HGS Asymmetry Groups				
Slow Gait Speed				
HGS Asymmetry >10.0% (n=4,865)†	1.21	1.11, 1.33	1.14	1.03, 1.26
HGS Asymmetry >20.0% (n=2,462)‡	1.29	1.17, 1.43	1.19	1.07, 1.33
HGS Asymmetry >30% (n=1,216)¥	1.36	1.20, 1.55	1.16	1.01, 1.35
Poorer Standing Balance				
HGS Asymmetry >10.0% (n=4,865)†	1.24	1.13, 1.36	1.20	1.09, 1.32
HGS Asymmetry >20.0% (n=2,462)‡	1.35	1.23, 1.49	1.27	1.15, 1.41
HGS Asymmetry >30% (n=1,216)¥	1.48	1.31, 1.67	1.31	1.16, 1.49
Continuous HGS Asymmetry				
Slow Gait Speed				
Every 10% HGS Asymmetry Increase	1.85	1.43, 2.41	1.25	0.96, 1.63
Poorer Standing Balance				
Every 10% HGS Asymmetry Increase	1.98	1.61, 2.43	1.62	1.32, 1.99

†Reference: HGS asymmetry 0.0%-10.0% (n=3,531); ‡Reference: HGS asymmetry 0.0%-20.0% (n=5,934); ¥Reference: HGS asymmetry 0.0%-30.0% (n=7,180).

Note: Fully-adjusted models controlled for age, sex, weakness, race, multimorbidity status, obesity status, self-rated health, social engagement, cognitive functioning, depression, moderate-to-vigorous physical activity, current smoking status, and smoking history. HGS=handgrip strength.

Table 3. Results for the Associations of the Handgrip Strength Asymmetry Groups on Continuous Gait Speed.

	Crude Models		Fully-Adjusted Models	
	β	**95% Confidence Interval**	**β**	**95% Confidence Interval**
Combined HGS Asymmetry Groups†				
HGS Asymmetry 10.1%-20.0% (n=2,402)	-0.01	-0.03, -0.01	-0.01	-0.02, 0.01
HGS Asymmetry 20.1%-30.0% (n=1,246)	-0.02	-0.03, -0.01	-0.01	-0.02, 0.01
HGS Asymmetry >30.0% (n=1,216)	-0.06	-0.07, -0.04	-0.03	-0.04, -0.02
Individual HGS Asymmetry Groups				
HGS Asymmetry >10.0% (n=4,864)†	-0.03	-0.04, -0.02	-0.01	-0.02, -0.01
HGS Asymmetry >20.0% (n=2,462)‡	-0.03	-0.04, -0.02	-0.02	-0.03, -0.01
HGS Asymmetry >30% (n=1,216)¥	-0.05	-0.06, -0.04	-0.02	-0.03, -0.01
Continuous HGS Asymmetry				
Every 10% HGS Asymmetry Increase	-0.09	-0.12, -0.07	-0.05	-0.07, -0.03

†Reference: HGS asymmetry 0.0%-10.0% (n=3,530); ‡Reference: HGS asymmetry 0.0%-20.0% (n=5,932); ¥Reference: HGS asymmetry 0.0%-30.0% (n=7,178).

Note: Fully-adjusted models controlled for age, sex, weakness, race, multimorbidity status, obesity status, self-rated health, social engagement, cognitive functioning, depression, moderate-to-vigorous physical activity, current smoking status, and smoking history. HGS=handgrip strength.

Supplementary Table 1. Means and 95% Confidence Intervals for the Descriptive Characteristics of the Participants.

	Overall	HGS Asymmetry 0.0%-10.0%	HGS Asymmetry 10.1%-20.0%	HGS Asymmetry 20.1%-30.0%	HGS Asymmetry >30.0%
Age (years)	76.1 (45.9, 76.2)	75.7 (75.4, 75.9)	76.0 (75.7, 76.3)	76.2 (75.8, 76.6)	77.1 (76.7, 77.5)
Young Old (%)	46.4 (45.4, 47.5)	48.5 (46.9, 50.2)	46.5 (44.6, 48.5)	45.9 (43.1, 48.7)	40.7 (38.0, 43.5)
Maximal Handgrip Strength (kilograms)	28.0 (27.8, 28.2)	28.3 (27.9, 28.6)	28.6 (28.2, 29.0)	28.1 (27.6, 28.7)	26.2 (25.7, 26.8)
Weakness (%)	41.2 (40.1, 42.2)	43.3 (41.7, 45.0)	38.7 (36.8, 40.7)	37.2 (34.6, 39.9)	43.8 (41.0, 46.6)
Female (%)	56.1 (55.0, 57.1)	52.7 (51.0, 54.3)	55.1 (53.1, 57.1)	60.1 (57.4, 62.8)	63.5 (60.8, 66.2)
White Race (%)	83.8 (83.1, 84.6)	84.7 (83.5, 85.8)	83.6 (82.2, 85.1)	83.7 (81.7, 85.8)	82.0 (79.8, 84.2)
Body Mass Index (kg/m^2)	27.5 (27.4, 27.6)	27.5 (27.3, 27.7)	27.5 (27.3, 27.7)	27.6 (27.3, 27.9)	27.4 (27.1, 27.7)
Obesity (%)	27.9 (27.0, 28.9)	28.4 (26.9, 29.8)	27.7 (25.9, 29.5)	26.7 (24.2, 29.1)	28.3 (25.8, 30.8)
Health Conditions	2.6 (2.5, 2.6)	2.5 (2.4, 2.5)	2.6 (2.5, 2.6)	2.6 (2.5, 2.7)	2.7 (2.6, 2.7)
Multimorbidity (%)	76.2 (75.3, 77.1)	75.3 (73.9, 76.7)	76.4 (74.7, 78.1)	76.6 (74.2, 78.9)	78.2 (75.9, 80.5)
TICS Score	20.8 (20.7, 20.9)	21.0 (20.8, 21.2)	20.8 (20.5, 21.0)	20.9 (20.6, 21.2)	20.4 (20.1, 20.7)
Cognitive Impairment (%)	3.9 (3.5, 4.3)	3.7 (3.1, 4.3)	4.0 (3.3, 4.8)	3.9 (2.8, 4.9)	4.0 (2.9, 5.1)
Fair or Poor Perceived Health (%)	30.1 (29.1, 31.1)	28.6 (27.1, 30.1)	31.6 (29.7, 33.4)	30.5 (27.9, 33.1)	31.2 (28.6, 33.8)
CES-D Score	1.3 (1.3, 1.4)	1.3 (1.2, 1.4)	1.4 (1.3, 1.5)	1.2 (1.1, 1.3)	1.4 (1.3, 1.6)
Depression (%)	12.0 (11.3, 12.6)	11.5 (10.4, 12.5)	12.7 (11.4, 14.1)	11.5 (9.7, 13.3)	12.3 (10.4, 14.1)
Social Engagement	1.1 (1.0, 1.1)	1.1 (1.1, 1.2)	1.1 (1.0, 1.1)	1.1 (1.0, 1.1)	1.0 (1.0, 1.1)
Current Smoker (%)	9.7 (9.0, 10.3)	9.9 (8.9, 10.8)	10.3 (9.1, 11.5)	9.1 (7.5, 10.7)	8.4 (6.8, 10.0)
Never Smoked (%)	42.2 (41.2, 43.3)	41.1 (39.4, 42.7)	41.2 (39.2, 43.1)	44.4 (41.6, 47.1)	45.6 (42.8, 48.4)
MVPA Participation (%)	50.3 (49.2, 51.3)	51.6 (50.0, 53.2)	49.3 (47.3, 51.3)	51.4 (48.6, 54.1)	47.2 (44.4, 50.0)
Gait Speed (m/s)	0.73 (0.72, 0.74)	0.75 (0.74, 0.75)	0.73 (0.72, 0.74)	0.73 (0.72, 0.74)	0.69 (0.68, 0.70)
Slow Gait Speed (%)	62.8 (61.8, 63.9)	60.2 (58.6, 61.8)	62.4 (60.5, 64.3)	65.3 (62.6, 67.9)	68.8 (66.2, 71.4)
Balance Score (%)					
0	0.3 (0.2, 0.4)	0.3 (0.1, 0.5)	0.3 (0.1, 0.5)	0.2 (0.1, 0.4)	0.7 (0.1, 1.1)
1	8.5 (7.8, 9.0)	7.4 (6.5, 8.2)	8.5 (7.4, 9.6)	9.2 (7.6, 10.8)	10.6 (8.9, 12.3)
2	12.0 (11.3, 12.7)	10.9 (9.9, 11.9)	11.8 (10.5, 13.7)	12.3 (10.5, 14.1)	15.4 (13.4, 17.5)
3	12.0 (11.3, 12.7)	11.5 (10.5, 12.6)	11.1 (9.9, 12.4)	13.2 (11.4, 15.1)	13.8 (11.9, 15.8)
4	67.2 (66.2, 68.2)	69.9 (68.4, 71.4)	68.3 (66.5, 70.2)	65.1 (62.4, 67.7)	59.5 (56.7, 62.2)

Note: CED-D=center for the epidemiologic studies-depression, HGS=handgrip strength, kg/m^2=kilograms per meters-squared, m/s=meters per second, MVPA=moderate-to-vigorous physical activity, TICS=telephone interview of cognitive status, Young Old=aged 65-74 years.

Supplementary Table 2. Results for the Associations of the Handgrip Strength Asymmetry Groups on Gait Speed and Standing Balance by Sex.

	Odds Ratio	95% Confidence Interval
Combined Handgrip Strength Asymmetry Groups		
Slow Gait Speed in Males		
Handgrip Strength Asymmetry 10.1%-20.0%	1.10	0.93, 1.31
Handgrip Strength Asymmetry 20.1%-30.0%	1.27	1.02, 1.59
Handgrip Strength Asymmetry >30.0%	1.24	0.98, 1.57
Poorer Standing Balance in Males		
Handgrip Strength Asymmetry 10.1%-20.0%	1.11	0.93, 1.33
Handgrip Strength Asymmetry 20.1%-30.0%	1.35	1.08, 1.68
Handgrip Strength Asymmetry >30.0%	1.31	1.04, 1.64
Slow Gait Speed in Females		
Handgrip Strength Asymmetry 10.1%-20.0%	1.04	0.88, 1.23
Handgrip Strength Asymmetry 20.1%-30.0%	1.20	0.98, 1.48
Handgrip Strength Asymmetry >30.0%	1.23	0.99, 1.51
Poorer Standing Balance in Females		
Handgrip Strength Asymmetry 10.1%-20.0%	1.07	0.92, 1.24
Handgrip Strength Asymmetry 20.1%-30.0%	1.18	0.98, 1.41
Handgrip Strength Asymmetry >30.0%	1.45	1.22, 1.73
Individual Handgrip Strength Asymmetry Groups		
Slow Gait Speed in Males		
Handgrip Strength Asymmetry >10.0%	1.17	1.01, 1.35
Handgrip Strength Asymmetry >20.0%	1.21	1.03, 1.43
Handgrip Strength Asymmetry >30%	1.16	0.93, 1.45
Poorer Standing Balance in Males		
Handgrip Strength Asymmetry >10.0%	1.21	1.04, 1.40
Handgrip Strength Asymmetry >20.0%	1.27	1.08, 1.50
Handgrip Strength Asymmetry >30%	1.20	0.97, 1.49
Slow Gait Speed in Females		
Handgrip Strength Asymmetry >10.0%	1.13	0.98, 1.30
Handgrip Strength Asymmetry >20.0%	1.20	1.03, 1.39
Handgrip Strength Asymmetry >30%	1.17	0.97, 1.41
Poorer Standing Balance in Females		
Handgrip Strength Asymmetry >10.0%	1.20	1.06, 1.36
Handgrip Strength Asymmetry >20.0%	1.28	1.13, 1.46
Handgrip Strength Asymmetry >30%	1.38	1.18, 1.61

Continuous Handgrip Strength Asymmetry		
Slow Gait Speed in Males		
Every 10% Handgrip Strength Asymmetry Increase	1.38	1.94, 2.02
Poorer Standing Balance in Males		
Every 10% Handgrip Strength Asymmetry Increase	1.49	1.11, 2.00
Slow Gait Speed in Females		
Every 10% Handgrip Strength Asymmetry Increase	1.18	0.82, 1.70
Poorer Standing Balance in Females		
Every 10% Handgrip Strength Asymmetry Increase	1.77	1.32, 2.36

Supplementary Table 3. Results for the Associations of the Handgrip Strength Asymmetry Groups on Continuous Gait Speed by Sex.

	β	95% Confidence Interval
Combined Handgrip Strength Asymmetry Groups		
Males		
Handgrip Strength Asymmetry 10.1%-20.0%	-0.02	-0.04, -0.01
Handgrip Strength Asymmetry 20.1%-30.0%	-0.02	-0.04, 0.01
Handgrip Strength Asymmetry >30.0%	-0.03	-0.05, -0.01
Females		
Handgrip Strength Asymmetry 10.1%-20.0%	-0.01	-0.02, 0.01
Handgrip Strength Asymmetry 20.1%-30.0%	-0.01	-0.03, 0.01
Handgrip Strength Asymmetry >30.0%	-0.03	-0.05, -0.01
Individual Handgrip Strength Asymmetry Groups		
Males		
Handgrip Strength Asymmetry >10.0%	-0.02	-0.04, -0.01
Handgrip Strength Asymmetry >20.0%	-0.02	-0.03, 0.01
Handgrip Strength Asymmetry >30%	-0.02	-0.04, 0.01
Females		
Handgrip Strength Asymmetry >10.0%	-0.01	-0.02, 0.01
Handgrip Strength Asymmetry >20.0%	-0.02	-0.03, -0.01
Handgrip Strength Asymmetry >30%	-0.03	-0.04, -0.01
Continuous Handgrip Strength Asymmetry		
Males		
Every 10% Handgrip Strength Asymmetry Increase	-0.05	-0.08, -0.01
Females		
Every 10% Handgrip Strength Asymmetry Increase	-0.05	-0.08, -0.02

Supplementary Table 4. Results for the Associations of the Handgrip Strength Asymmetry Groups on Gait Speed and Standing Balance Without Cognitive Function as a Covariate.

	Odds Ratio	95% Confidence Interval
Combined Handgrip Strength Asymmetry Groups		
Slow Gait Speed		
Handgrip Strength Asymmetry 10.1%-20.0%	1.04	0.94, 1.16
Handgrip Strength Asymmetry 20.1%-30.0%	1.22	1.07, 1.39
Handgrip Strength Asymmetry >30.0%	1.20	1.05, 1.37
Poorer Standing Balance		
Handgrip Strength Asymmetry 10.1%-20.0%	1.11	1.01, 1.23
Handgrip Strength Asymmetry 20.1%-30.0%	1.25	1.11, 1.41
Handgrip Strength Asymmetry >30.0%	1.39	1.23, 1.56
Individual Handgrip Strength Asymmetry Groups		
Slow Gait Speed		
Handgrip Strength Asymmetry >10.0%	1.13	1.02, 1.22
Handgrip Strength Asymmetry >20.0%	1.19	1.08, 1.31
Handgrip Strength Asymmetry >30%	1.14	1.01, 1.29
Poorer Standing Balance		
Handgrip Strength Asymmetry >10.0%	1.21	1.12, 1.32
Handgrip Strength Asymmetry >20.0%	1.26	1.16, 1.38
Handgrip Strength Asymmetry >30%	1.28	1.15, 1.43
Continuous Handgrip Strength Asymmetry		
Slow Gait Speed		
Every 10% Handgrip Strength Asymmetry Increase	1.35	1.07, 1.71
Poorer Standing Balance		
Every 10% Handgrip Strength Asymmetry Increase	1.64	1.37, 1.97

Supplementary Table 5. Results for the Associations of the Handgrip Strength Asymmetry Groups on Continuous Gait Speed Without Cognitive Function as a Covariate.

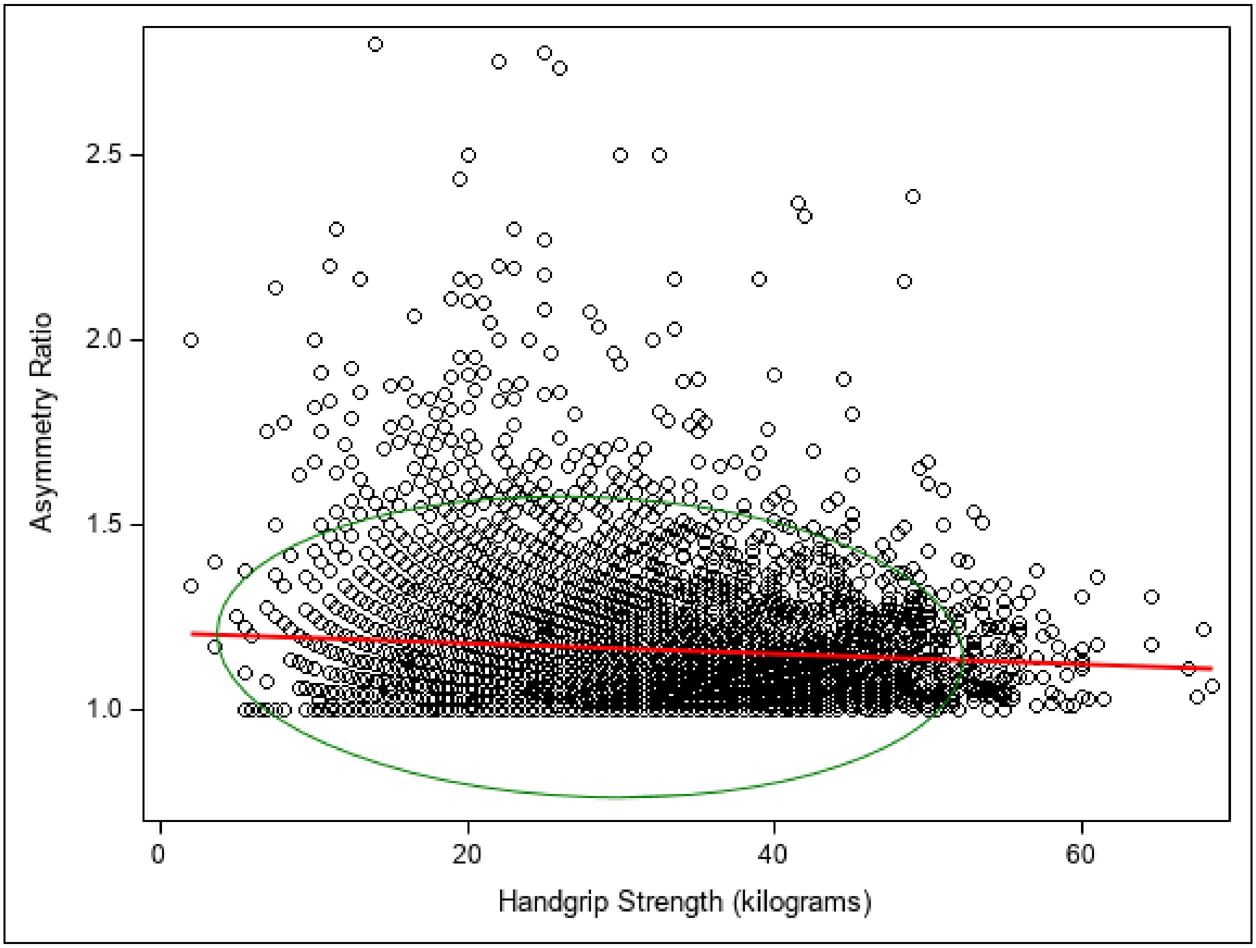
	β	95% Confidence Interval
Combined Handgrip Strength Asymmetry Groups		
Handgrip Strength Asymmetry 10.1%-20.0%	-0.01	-0.02, 0.01
Handgrip Strength Asymmetry 20.1%-30.0%	-0.02	-0.03, -0.01
Handgrip Strength Asymmetry >30.0%	-0.03	-0.04, -0.02
Individual Handgrip Strength Asymmetry Groups		
Handgrip Strength Asymmetry >10.0%	-0.02	-0.02, -0.01
Handgrip Strength Asymmetry >20.0%	-0.02	-0.03, -0.01
Handgrip Strength Asymmetry >30%	-0.02	-0.03, -0.01
Continuous Handgrip Strength Asymmetry		
Every 10% Handgrip Strength Asymmetry Increase	-0.05	-0.07, -0.03

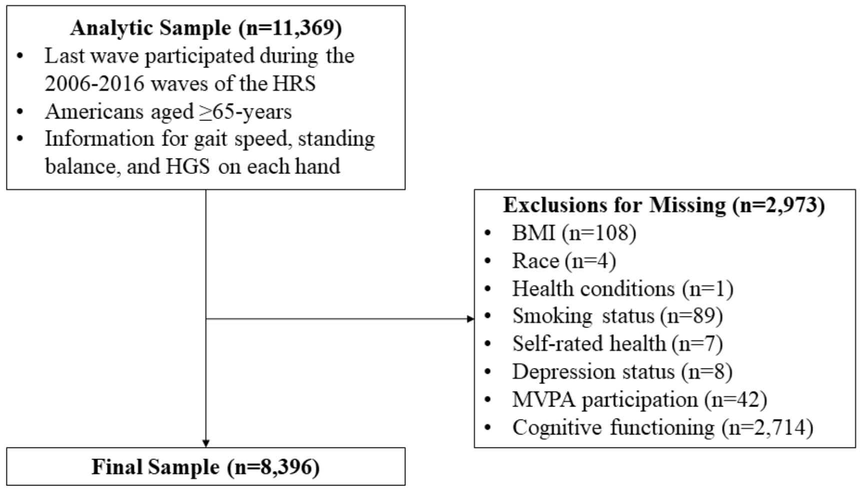
Supplementary Table 6. Results for the Associations of the Handgrip Strength Asymmetry Groups on Gait Speed and Standing Balance with Relevant Continuous Covariates in the Models and Stroke as a Stand-Alone Covariate.

	Odds Ratio	**95% Confidence Interval**
Combined Handgrip Strength Asymmetry Groups		
Slow Gait Speed		
Handgrip Strength Asymmetry 10.1%-20.0%	1.04	0.92, 1.18
Handgrip Strength Asymmetry 20.1%-30.0%	1.21	1.03, 1.41
Handgrip Strength Asymmetry >30.0%	1.16	0.99, 1.36
Poorer Standing Balance		
Handgrip Strength Asymmetry 10.1%-20.0%	1.05	0.93, 1.18
Handgrip Strength Asymmetry 20.1%-30.0%	1.19	1.03, 1.38
Handgrip Strength Asymmetry >30.0%	1.32	1.15, 1.52
Individual Handgrip Strength Asymmetry Groups		
Slow Gait Speed		
Handgrip Strength Asymmetry >10.0%	1.11	1.01, 1.23
Handgrip Strength Asymmetry >20.0%	1.16	1.04, 1.30
Handgrip Strength Asymmetry >30%	1.11	0.85, 1.28
Poorer Standing Balance		
Handgrip Strength Asymmetry >10.0%	1.15	1.05, 1.27
Handgrip Strength Asymmetry >20.0%	1.23	1.11, 1.36
Handgrip Strength Asymmetry >30%	1.26	1.11, 1.43
Continuous Handgrip Strength Asymmetry		
Slow Gait Speed		
Every 10% Handgrip Strength Asymmetry Increase	1.13	0.86, 1.48
Poorer Standing Balance		
Every 10% Handgrip Strength Asymmetry Increase	1.46	1.18, 1.80

Supplementary Table 7. Results for the Associations of the Handgrip Strength Asymmetry Groups on Continuous Gait Speed with Relevant Continuous Covariates in the Models and Stroke as a Stand-Alone Covariate.

	β	**95% Confidence Interval**
Combined Handgrip Strength Asymmetry Groups		
Handgrip Strength Asymmetry 10.1%-20.0%	-0.01	-0.02, 0.01
Handgrip Strength Asymmetry 20.1%-30.0%	-0.01	-0.02, 0.01
Handgrip Strength Asymmetry >30.0%	-0.02	-0.03, -0.01
Individual Handgrip Strength Asymmetry Groups		
Handgrip Strength Asymmetry >10.0%	-0.01	-0.02, -0.01
Handgrip Strength Asymmetry >20.0%	-0.01	-0.02, -0.01
Handgrip Strength Asymmetry >30%	-0.01	-0.03, -0.01
Continuous Handgrip Strength Asymmetry		
Every 10% Handgrip Strength Asymmetry Increase	-0.03	-0.06, -0.01


Asymmetry Ratio
2.5
2.0
1.5
1.0
0
20
40
60
Handgrip Strength (kilograms)


Analytic Sample (n=11,369)
Last wave participated during the 2006-2016 waves of the HRS
Americans aged ≥65-years
Information for gait speed, standing balance, and HGS on each hand
Exclusions for Missing (n=2,973)
BMI (n=108)
Race (n=4)
Health conditions (n=1)
Smoking status (n=89)
Self-rated health (n=7)
Depression status (n=8)
MVPA participation (n=42)
Cognitive functioning (n=2,714)
Final Sample (n=8,396)