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# Muscle Strength and Functional Limitations: Preserving Function in Older Mexican Americans

**Ryan McGrath, PhD**[a,*], **Sheria G. Robinson-Lane, PhD, RN**[b], **Mark D. Peterson, PhD, MS**[a], **Ryan R. Bailey, PhD, OTR/L**[c], and **Brenda M. Vincent, MS**[d]

[a]Department of Physical Medicine and Rehabilitation, University of Michigan, Ann Arbor, MI

[b]School of Nursing, University of Michigan, Ann Arbor, MI

[c]Department of Psychiatry, Washington University in St. Louis, St. Louis, MO

[d]Center for Clinical Management Research, VA Ann Arbor Healthcare System, Ann Arbor, MI

## Abstract

**Objectives:** Understanding the role of muscle strength as a preventive factor for shorter-term declines in function may provide further insights into the disabling process. This study examined if muscle strength was associated with 2-year preservation of instrumental activities of daily living (IADL) function and activities of daily living (ADL) disability status in older Mexican Americans.

**Design:** Longitudinal, panel.

**Setting:** Urban and rural households in the Southwestern United States.

**Participants:** A subsample of 672 Mexican Americans aged at least 65 years was followed for 2 years.

**Measurements:** Muscle strength was assessed with a hand-held dynamometer. IADL and ADL were self-reported. Covariate-adjusted ordinal and multinomial logistic models were used to determine the association between handgrip strength and changes in IADL function, and ADL disability status over 2 years.

**Results:** Every 10-kg increase in handgrip strength was associated with 5% decreased odds [odds ratio (OR): 0.95; 95% confidence interval (CI): 0.92, 0.98] of experiencing a lost IADL function in 2 years. Likewise, every 10-kg increase in handgrip strength was associated with an 8% decreased odds (OR: 0.92; CI: 0.88, 0.97) for 2-year onset ADL disability, 12% decreased odds (OR: 0.88; CI: 0.83, 0.94) for 2-year ADL disability progression, and 7% decreased odds (OR: 0.93; CI: 0.89, 0.98) for 2-year ADL disability improvement, compared to those with no ADL disability at baseline and follow-up.

**Conclusions:** Higher muscle strength was related to a lower risk for 2-year onset of IADL and ADL disability in older Mexican Americans. Future investigations are warranted to examine how

[*]Address correspondence to Ryan McGrath, PhD, Department of Physical Medicine and Rehabilitation, Michigan Medicine, University of Michigan, 325 E. Eisenhower Pkwy., Suite 300, Ann Arbor, MI 48108. mcgratry@med.umich.edu (R. McGrath).

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potential mediators influence the association between muscle strength and function, to inform interventions aiming to retain function in vulnerable older adult populations.

**Keywords**

Activities of daily living; frail elderly; geriatrics; muscle weakness; pain

The declines in muscle strength that occur over the life course reflect the reductions in muscle mass and function that take place as adults age.[1,2] Muscle strength is often measured with a hand-held dynamometer, a simple and feasible metric intended to assess overall strength capacity. Not only is low handgrip strength associated with poor health outcomes such as diabetes and an activities of daily living (ADL) disability,[3–5] it is also associated with all-cause mortality.[6] Moreover, low handgrip strength is a factor in the development of sarcopenia, which in turn, is associated with an increased risk for an ADL disability.[7] Therefore, handgrip strength is an important biomarker of frailty and should be used for detecting sarcopenia and disease risk as adults age.[8,9] A population of particular concern is older Hispanic Americans, as they have lower skeletal muscle mass across the life span compared to Whites and African Americans.[1]

Measures of functional limitations are often assessed in older adults to determine self-care ability and independence. A person's ability to perform ADL (e.g., bathing, grooming, dressing) is a determinant of his or her functional status,[10] whereas instrumental activities of daily living (IADL; e.g., shopping, driving, managing money) are needed for independent functioning in a community.[11] When someone reports that they need help performing or are unable to perform any of these activities, they are usually considered as having an ADL or IADL disability. These types of functional limitations are problematic because a variety of poor clinically relevant health outcomes have been linked to any number of ADL and IADL impairments.[12,13] However, the presence or absence of a functional limitation based on standard definitions may not provide enough details into the progression of the disabling process and its associated health consequences.

Previous investigations have found that changes in the status of a functional impairment were associated with frailty, nursing home visits, and death.[14,15] Because greater muscle strength is associated with a lower hazard for an ADL disability in older Mexican Americans over a 7- and 19-year time period,[5,16] examining if greater muscle strength is associated with shorter-term losses of IADL function and ADL disability status may uncover additional details into the disabling process. This may then help identify potential mediators for muscle strength and functional impairments, and inform targeted interventions seeking to preserve function in this growing population. Therefore, this study sought to determine if greater muscle strength was associated with 2-year (1) preservation of IADL functioning, and (2) improvements in ADL disability status in older Mexican Americans.

## Methods

### Participants

Data were analyzed from the Hispanic Established Populations for Epidemiologic Studies of the Elderly (HEPESE) Frailty Study, a continuation of the HEPESE that investigated the enabling-disabling process in older Mexican Americans. To be included in the Frailty Study, participants had to be Mexican American, enrolled in the larger HEPESE Study, aged at least 65 years, physically able to complete the muscle strength measures safely at baseline, and residing in Arizona, California, Colorado, New Mexico, or Texas. Baseline interviews were conducted in 2006–2007 and follow-up data were collected in 2008–2009. Details of the sampling plan and cohort have been described previously.[17] All participants provided written informed consent and study protocols were approved by the University of Texas Medical Branch Institutional Review Board.

### Measures

**Explanatory Variable—**Muscle strength was assessed with a hand-held dynamometer (Jamar Hydraulic Dynamometer; J.A. Preston Corporation, New York, NY). The use of a hand-held dynamometer to assess muscle strength has shown to be reliable and valid in older Mexican American adults.[16] Participants who had surgery to the hand or wrist in the previous 3 months were excluded from the handgrip strength test. After explaining the protocol and demonstrating the handgrip strength test, trained interviewers adjusted the grip size of the dynamometer to the hand size of each participant so they could perform a practice trial. A scale size of 5, 6, or 7 on the dynamometer was used for smaller, midsized, and larger hands, respectively. During the 2-test trials, participants remained seated with their arm resting on a table as they squeezed the dynamometer using an underhand grip with their dominant hand in the supinated position, exhaling while squeezing with maximal exertion. Verbal encouragement was provided by interviewers to further induce participant effort. The highest value of the 2-test trials performed was included.

**Response Variables—**The Older Americans Resources and Services IADL scale and the Rosow-Breslau scale were used to assess IADL functioning at baseline and follow-up.[18,19] Participants were asked about their ability to use a telephone, drive, shop, prepare meals, perform light housework, take medications, manage money, do heavy housework, walk up and down stairs, and walk a half-mile. Those that indicated they were unable to perform any number of these 10 tasks were identified as having lost that particular IADL function.

A modified version of the Katz ADL scale was used to assess ADL disability status.[20] Participants reported if they could walk across a small room; bathe; groom; get dressed; eat; transfer from bed to chair; and toilet either without help, with help, or were unable to perform the activity. Those indicating they needed help or were unable to perform any of these activities were identified as having lost that specific ADL function and were also considered as having an ADL disability.

Participants with no ADL disability at baseline and follow-up were categorized as not having an ADL disability. Onset ADL disability was defined as having no ADL disability at

baseline but having an ADL disability at follow-up. Persistent ADL disability was defined as having lost an ADL function at baseline and without the same ADL function at follow-up, whereas ADL disability progression was defined as having an ADL disability at baseline and then having an increase in the number of ADL functions lost at follow-up. ADL disability improvement was defined as having an ADL disability at baseline and then having a decrease in the number of ADL functions lost or no ADL disability at follow-up.[21]

**Covariates—**Participants self-reported age, sex, diabetes diagnosis, falls in the previous year (falls, no falls), and perceived health status (excellent, good, fair, poor).[17] A Metro 9800 scale (Metro Scale & Systems Inc; Fort Myers, FL) was used to determine body weight, and participants stood by a tape measure against a wall to determine height. Body mass index (BMI) was calculated by taking the quotient of body weight in kilograms by height in meters-squared.

Participants were asked to recall their physical activity levels over the previous 7 days using the Physical Activity Scale for the Elderly (PASE).[22] For each sex, those scoring in the lowest 20% of the PASE were considered physically inactive.[17,23] Exhaustion was determined using 2 items from the Center for Epidemiologic Studies–Depression Scale (CES-D).[17] Those indicating that they felt “everything was an effort” and “could not get going” for at least a moderate amount of time (≥3 days/week) on either item were considered chronically exhausted.[23] Pain interference was measured with a single item from the Medical Outcomes Study Short Form-36 Health Survey.[17,24] Participants responding to “during the past four weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?” that they had a little bit, moderate, quite a bit, or extreme pain were considered as having pain interference. Walking speed was recorded from an 8-foot walking test. Participants who were unable to complete the walk test or who scored in the lowest 20% for their sex and height were considered as having a slow walking speed.[17] Those reporting an unintentional weight loss of at least 10 lbs since the last interview were considered as experiencing an unexplained loss of weight.[17,23]

**Descriptive Information—**Participants self-reported if they were married, diagnosed with a stroke or hypertension, were taking medications for their diabetes or hypertension, and the number of people living in their household. The CES-D was used to assess mental health. Those with scores of ≥16 were considered depressed.[25]

## Statistical Analysis

Analyses were conducted with SAS 9.4 software (SAS; Cary, NC). Independent t-tests and chi-squared tests were performed to determine differences in the baseline descriptive characteristics of the participants by sex. An ordinal logistic regression model was used to determine if handgrip strength was associated with 2-year preservation of IADL functioning after adjusting for the number of IADL impairments at baseline, age, BMI, sex, previous falls, diabetes diagnosis, perceived health-status, physical inactivity, pain interference, unexplained weight loss, chronic exhaustion, and slow walking speed. The ordinal logit model did not violate the proportional odds assumption.

A multinomial logistic regression model was used to determine if handgrip strength was associated with 2-year onset ADL disability, persistent ADL disability, ADL disability progression, and ADL disability improvement, using no ADL disability at baseline and follow-up as the reference. The model was adjusted for age, BMI, sex, previous falls, diabetes diagnosis, perceived health status, physical inactivity, pain interference, unexplained weight loss, chronic exhaustion, and slow walking speed. An alpha level of 0.05 was used for all analyses.

The same covariate-adjusted ordinal and multinomial logistic regression models were performed with handgrip strength dichotomized for each sex using Foundation for the National Institutes of Health (FNIH) Sarcopenia Project cut-points.[26] These results were presented as an appendix because dichotomizing handgrip strength with these cut-points was not part of our *a priori* research questions.

To assess the impact of missing data from covariates and participant drop-out after baseline measures, multiple imputation was performed as a sensitivity analysis. Multiple imputation for missing variables was conducted separately for both the ordinal and multinomial logit models. The multiple imputation models were imputed 5 times using participants included in baseline measures. The variables in the imputed models were covariates that were adjusted for in the original analyses, but also included covariates that may have been linked to the cause of the missing data. These variables included the total number of IADL and ADL performed without help at baseline and follow-up, sex, handgrip strength, BMI, age, previous falls, diabetes diagnosis, perceived health-status, physical inactivity, unexplained weight loss, chronic exhaustion, slow walking speed, baseline total score on the CES-D, baseline total score on the PASE, baseline summary score on the Short Physical Performance Battery, and 8 baseline scale scores from the Medical Outcomes Study Short Form-36 (physical functioning, physical role functioning, bodily pain, general health perceptions, vitality, social role functioning, emotional role functioning, and mental health).[17,27–29]

Each of the 5 data sets was analyzed using the non-imputed ordinal and multinomial logistic models. The results were then combined using Rubin's rules.[30] A Markov chain Monte Carlo method was used to impute variables and a fully conditional specification method using discriminant function methods with 100 burn-in interactions was used for imputed health-status. For the imputed multinomial logit model, the total number of ADL at follow-up was first imputed and then participants were categorized as no ADL disability, onset ADL disability, persistent ADL disability, ADL disability progression, or ADL disability improvement. If any of the odds ratios (ORs) in the imputed models changed by more than 10% (*a priori* threshold) for handgrip strength compared to the ORs for handgrip strength in the non-imputed models, the results of the sensitivity analysis would instead be reported.[31]

## Results

Of the 730 participants who completed baseline and follow-up measures, exclusions occurred for those with missing handgrip strength (n = 15), BMI (n = 42), and ADL (n =1) data. Therefore, 672 participants with complete data were included and their descriptive

characteristics are presented in Table 1. For those included, 393 had no ADL disability at baseline and follow-up, 91 had onset ADL disability, 33 had persistent ADL disability, 64 had ADL disability progression, and 91 had an ADL disability improvement. Of the participants with follow-up measures for handgrip strength (overall n 484; males n = 168, females n = 316), the mean decrease from baseline to follow-up was 3.6 ± 6.4 kg overall, 4.6 ± 7.2 kg for males, and 3.1 ± 5.9 kg for females.

Table 2 shows the results for the association between handgrip strength and 2-year loss of IADL function. The covariate-adjusted ordinal logit model revealed that every 10-kg increase in handgrip strength was associated with 5% decreased odds [OR: 0.95; 95% confidence interval (CI): 0.92, 0.98] of losing an additional IADL function in 2 years.

Table 3 presents the results for the association between handgrip strength and changes in 2-year ADL disability status. The covariate-adjusted multinomial logistic model showed that for every 10-kg increase in handgrip strength, there was an 8% decreased odds (OR: 0.92; CI: 0.88, 0.97) for 2-year onset ADL disability, a 12% decreased odds (OR: 0.88; CI: 0.83, 0.94) for 2-year ADL disability progression, and a 7% decreased odds (OR: 0.93; CI: 0.89, 0.98) for 2-year ADL disability improvement, compared to those having no ADL disability at baseline and follow-up. Handgrip strength was not significantly associated with persistent ADL disability when compared to those with no ADL disability at baseline and follow-up (OR: 0.96; CI: 0.89, 1.04).

Appendix 1 presents the results for the association between dichotomized handgrip strength and 2-year loss of IADL function, whereas Appendix 2 shows the results for the association between dichotomized handgrip strength and 2-year ADL disability status. The results of the multiple imputation ordinal and multinomial logistic regression models are presented in Appendices 3 and 4, respectively. There were no changes in the ORs of more than 10% when comparing the results of the non-imputed models to those of the imputed models for handgrip strength, thereby suggesting that missing data did not have a significant impact on the results.

## Discussion

The principal findings from this investigation suggest that greater muscle strength was associated with decreased odds of 2-year losses in IADL function in older Mexican Americans. Moreover, greater muscle strength decreased the odds of 2-year onset ADL disability, ADL disability progression, and ADL disability improvement when compared to no ADL disability at baseline and follow-up. These findings underscore the importance of maintaining muscle strength as a means of preventing the progression of the short-term disabling process.

The results of this investigation demonstrate the importance of muscle strength on preserving 2-year IADL function in older Mexican Americans. Similar results were presented in an investigation of obese older adults, wherein having a higher handgrip strength was associated with decreased odds of an IADL disability.[32] Another investigation showed that older adults with the greatest muscle strength had the lowest odds for IADL

disability.[33] However, the dynamic process of losing and regaining IADL function should be noted, especially in older adults that experience improvements in perceived health.[34,35]

Muscle weakness has also been shown to be associated with an increased risk for ADL disability in older Mexican Americans over 7- and 19-year time periods.[5,16] However, it remains unclear how muscle strength impacts shorter-term changes in ADL disability status for this population. The results of our investigation revealed that greater handgrip strength was associated with decreased odds for onset ADL disability and ADL disability progression when using no ADL disability at baseline and follow-up as the reference. Our results indicating greater handgrip strength was associated with decreased odds for ADL disability improvement probably occurred because those not having an ADL disability at baseline and follow-up (group with the highest function) were the reference. Acknowledging how ADL functions shift over a short period of time further demonstrates the mutable nature of ADL. Similar findings were presented in an investigation of White and African American older adults, wherein dichotomized (weak, not-weak) muscle weakness was associated with an increased odds of ADL disability onset, progression, persistence, and improvement compared to those with no ADL disability.[21]

Our results are compatible with those from the FNIH Sarcopenia Project, wherein those beneath the weakness cut-points for mobility impairment had greater odds for a variety of poor health outcomes.[36] However, presenting handgrip strength as a continuous variable may uncover details that dichotomized weakness (above and below thresholds) may not, thereby providing more thorough insights into the role of handgrip strength on different clinically relevant health outcomes.[37] Standardized weakness cut-points should also continue to be refined with respect to ethnicity,[38] as similar cut-points have revealed ethnic differences in weakness thresholds, and such cut-points for Hispanic Americans remain absent.[39] Moreover, understanding how handgrip strength differentially affects disaggregated ADL limitations and subsequent time to mortality may provide further insights into the disabling process; and how future weakness thresholds can be more all-encompassing for health outcomes. Such pathways to evaluating muscle weakness may help move the use of hand-held dynamometers and standardized weakness assessments into practice for clinicians and their patients.

During the aging process, older adults experience reductions in skeletal muscle mass and increases in fat mass.[40] In women, greater handgrip strength is associated with decreased odds for osteoporosis, and diminished bone mineral density overlaps with the age-related changes in body composition.[41,42] Therefore, it is especially important for individuals to maintain adherence to healthy lifestyle behaviors that increase skeletal muscle mass earlier in life to mitigate the effects of age-related body composition changes later in life. Persons that engage in such healthy lifestyle behaviors early in life may experience greater muscle area over time compared to those who do not, thereby reducing their risk of frailty and functional disability.[2,43]

It should be highlighted that pain interference was robustly associated with 2-year reductions in IADL and ADL function. Addressing pain management and other health factors for minority older adult populations is often challenging because of the gaps between health

care providers and consumers.[44] Our results support the growing need for culturally responsive interventions that target healthy behavior adherence for pain management and improvement in function for Hispanic older adults and other vulnerable populations. Multidisciplinary teams should consider how to further develop programs that engage at risk populations for clinically relevant health outcomes by fulfilling multiple health domains. For example, engaging minority older adults in care that integrates important cultural values into the plan of care may increase positive health outcomes and equitable access to care that is in alignment with guidelines for culturally appropriate services.[45]

Understanding and addressing poor health behaviors that reduce muscle strength is an important step in intervention designs targeting function, particularly for those who are of Hispanic ethnicity because this ethnic group has lower handgrip strength and skeletal muscle mass across the life span compared to Whites and African Americans.[1,46] Future investigations should consider examining how the association between muscle strength and functional limitations is mediated by pain interference. This may help to inform additional strategies aimed at preserving IADL and ADL function in vulnerable populations. Uncovering ethnic differences for the mediating effect of pain on muscle strength and function may bolster the effectiveness of such interventions.

Some limitations of this study should be noted. Considering there was a 2-year period between baseline and follow-up measurements, acute health events that may have occurred could have influenced our results. There were also a small number of cases for certain ADL disability statuses, specifically for persistent ADL disability, which may have explained why this ADL disability status was a nonsignificant outcome for handgrip strength. Similarly, no participants reported an excellent health status in the persistent ADL disability group. Some factors that may have influenced the outcomes of this study such as cognition, dietary intake, current health care, and socioeconomic status were not collected in the HEPESE Frailty Study. Although our results underscore the association between muscle strength and 2-year loss of IADL function, and change in ADL disability status, these findings may not be generalizable to all older Mexican Americans.

This investigation has a number of strengths. The use of multiple imputation as a sensitivity analysis improved the robustness of our results. Mexican Americans are also a cohort of Hispanic Americans, and this population, along with the older adult population, is projected to grow quickly in the United States, thereby magnifying the implications of our results.[47,48]

## Conclusion

The results of this investigation suggest greater muscle strength was associated with decreased odds for 2-year loss of IADL functioning in older Mexican Americans. Likewise, greater muscle strength decreased the odds of 2-year onset ADL disability, ADL disability progression, and ADL disability improvement, compared to no ADL disability at baseline and follow-up. These results further demonstrate how muscle strength is associated with the disabling process. Health practitioners should encourage older Mexican Americans to engage in behaviors that promote the preservation of muscle strength for retaining IADL and ADL function. Short-term changes in ADL and IADL should be managed before

considering the long-term implications of lost ADL and IADL functions. Future investigations are needed to identify if certain factors, such as pain interference, mediate the association between muscle strength and function in vulnerable populations. This may help refine interventions interested in preserving IADL and ADL function.

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## Appendix 1

Results for the Association Between Dichotomized Handgrip Strength and 2-Year Loss of IADL Function

| | OR | 95% CI |
|---|---|---|
| Not-weak (reference: weak) | 0.62 | 0.45, 0.86 |
| Baseline IADL function | 1.79 | 1.61, 1.99 |
| Age | 1.15 | 1.11, 1.19 |
| Body mass index | 1.02 | 0.99, 1.05 |
| Female (reference: male) | 1.63 | 1.18, 2.25 |
| Previous falls (reference: no falls) | 0.93 | 0.67, 1.27 |
| Diabetes (reference: no diabetes) | 1.48 | 1.06, 2.06 |
| Physically inactive (reference: active) | 1.63 | 1.04, 2.55 |
| Unexplained weight loss (reference: no unexplained weight loss) | 1.30 | 0.89, 1.90 |
| Chronically exhausted (reference: not exhausted) | 0.84 | 0.57, 1.23 |
| Slow walking speed (reference: not slow) | 0.60 | 0.39, 0.93 |
| Pain interference (reference: no pain interference) | 1.48 | 1.06, 2.07 |
| Perceived health status (reference: poor) | | |
| Excellent | 0.52 | 0.23, 1.18 |
| Good | 0.69 | 0.39, 1.23 |
| Fair | 0.76 | 0.45, 1.26 |

Note. The model violated the proportional odds assumption.

IADL, instrumental activities of daily living.

## Appendix 2

Results for the Association Between Dichotomized Handgrip Strength and Changes in 2-Year ADL Disability Status

| | Onset ADL Disability* | | Persistent ADL Disability* | | ADL Disability Progression* | | ADL Disability Improvement* | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Not-weak (reference: weak) | 0.52 | 0.31, 0.85 | 0.75 | 0.33, 1.67 | 0.41 | 0.22, 0.76 | 0.66 | 0.39, 1.10 |
| Age | 1.09 | 1.03, 1.16 | 1.19 | 1.08, 1.31 | 1.19 | 1.11, 1.29 | 1.00 | 0.93, 1.07 |
| Body mass index | 1.03 | 0.98, 1.08 | 1.05 | 0.97, 1.13 | 1.05 | 0.99, 1.12 | 1.02 | 0.97, 1.07 |
| Female (reference: male) | 1.71 | 1.01, 2.91 | 1.08 | 0.47, 2.45 | 2.24 | 1.12, 4.45 | 1.26 | 0.75, 2.13 |

| | Onset ADL Disability* | | Persistent ADL Disability* | | ADL Disability Progression* | | ADL Disability Improvement* | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Previous falls (reference: no falls) | 0.81 | 0.48, 1.37 | 1.34 | 0.60, 2.97 | 0.79 | 0.42, 1.51 | 1.38 | 0.82, 2.29 |
| Diabetes (reference: no diabetes) | 1.55 | 0.92, 2.62 | 2.49 | 1.09, 5.66 | 1.44 | 0.74, 2.81 | 0.77 | 0.44, 1.36 |
| Physically inactive (reference: active) | 1.49 | 0.72, 3.10 | 1.84 | 0.69, 4.86 | 4.46 | 2.14, 9.28 | 1.92 | 0.94, 3.93 |
| Unexplained weight loss (reference: no unexplained weight loss) | 1.22 | 0.65, 2.29 | 0.71 | 0.24, 2.07 | 1.67 | 0.79, 3.53 | 1.86 | 1.03, 3.34 |
| Chronically exhausted (reference: not exhausted) | 1.43 | 0.79, 2.56 | 1.65 | 0.71, 3.85 | 0.45 | 0.20, 1.00 | 0.72 | 0.39, 1.32 |
| Slow walking speed (reference: not slow) | 0.66 | 0.31, 1.37 | 1.66 | 0.68, 4.02 | 0.62 | 0.26, 1.46 | 1.09 | 0.56, 2.13 |
| Pain interference (reference: no pain interference) | 1.79 | 1.04, 3.06 | 4.90 | 1.73, 13.86 | 3.56 | 1.74, 7.24 | 2.31 | 1.33, 4.02 |
| Perceived health status (reference: poor) | | | | | | | | |
| Excellent | 0.40 | 0.09, 1.79 | 0.00 | 0.00, 0.00 | 0.10 | 0.01, 0.99 | 0.10 | 0.01, 0.86 |
| Good | 0.80 | 0.30, 2.10 | 0.61 | 0.16, 2.31 | 0.19 | 0.06, 0.63 | 0.33 | 0.12, 0.90 |
| Fair | 1.01 | 0.42, 2.44 | 0.74 | 0.24, 2.23 | 0.68 | 0.28, 1.62 | 0.95 | 0.42, 2.14 |

ADL, activities of daily living; 95% CI, 95% confidence interval; OR, odds ratio; UWL, unexplained weight loss.

*Reference: No ADL disability at baseline and follow-up.

## Appendix 3

Results of the Multiple Imputation for the Association Between Handgrip Strength and 2-Year Loss of IADL Function

| | OR | 95% CI |
|---|---|---|
| Handgrip strength | 0.95 | 0.92, 0.98 |
| Baseline IADL function | 1.80 | 1.58, 2.04 |
| Age | 1.11 | 1.07, 1.15 |
| Body mass index | 1.01 | 0.98, 1.05 |
| Female (reference: male) | 0.87 | 0.62, 1.21 |
| Previous falls (reference: no falls) | 0.92 | 0.65, 1.30 |
| Diabetes (reference: no diabetes) | 1.43 | 1.05, 1.95 |
| Physically inactive (reference: active) | 1.39 | 0.97, 2.00 |
| Unexplained weight loss (reference: no unexplained weight loss) | 1.02 | 0.69, 1.51 |
| Chronically exhausted (reference: not exhausted) | 0.78 | 0.56, 1.10 |
| Slow walking speed (reference: not slow) | 0.76 | 0.48, 1.21 |
| Pain interference (reference: no pain interference) | 1.18 | 0.85, 1.62 |
| Perceived health status (reference: poor) | | |
| Excellent | 0.61 | 0.38, 0.96 |
| Good | 1.00 | 0.79, 1.26 |
| Fair | 1.10 | 0.88, 1.37 |

IADL, instrumental activities of daily living.

## Appendix 4

Results of the Multiple Imputation for the Association Between Handgrip Strength and Changes in 2-Year ADL Disability Status

| | Onset ADL Disability* | | Persistent ADL Disability* | | ADL Disability Progression* | | ADL Disability Improvement* | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Handgrip strength | 0.95 | 0.90, 0.99 | 0.91 | 0.84, 0.99 | 0.94 | 0.94, 0.94 | 0.89 | 0.85, 0.93 |
| Age | 1.07 | 1.02, 1.12 | 1.15 | 1.05, 1.25 | 1.17 | 1.10, 1.25 | 1.07 | 1.01, 1.14 |
| Body mass index | 1.02 | 0.98, 1.06 | 1.06 | 0.98, 1.13 | 1.06 | 0.99, 1.13 | 1.02 | 0.97, 1.08 |
| Female (reference: male) | 0.71 | 0.39, 1.31 | 0.49 | 0.19, 1.22 | 0.73 | 0.36, 1.49 | 0.54 | 0.30, 0.97 |
| Previous falls (reference: no falls) | 0.77 | 0.48, 1.25 | 0.84 | 0.44, 1.59 | 0.72 | 0.44, 1.20 | 1.19 | 0.77, 1.85 |
| Diabetes (reference: no diabetes) | 1.45 | 0.82, 2.56 | 2.11 | 0.99, 4.45 | 1.58 | 0.90, 2.77 | 0.98 | 0.59, 1.61 |
| Physically inactive (reference: active) | 1.61 | 0.82, 3.15 | 2.13 | 0.97, 4.70 | 4.77 | 2.59, 8.78 | 2.73 | 1.47, 5.07 |
| Unexplained weight loss (reference: no unexplained weight loss) | 1.06 | 0.52, 2.18 | 1.09 | 0.50, 2.39 | 1.52 | 0.82, 2.84 | 1.66 | 1.01, 2.72 |
| Chronically exhausted (reference: not exhausted) | 1.23 | 0.70, 2.15 | 1.27 | 0.66, 2.44 | 0.62 | 0.31, 1.22 | 0.87 | 0.52, 1.46 |
| Slow walking speed (reference: not slow) | 0.79 | 0.34, 1.81 | 2.73 | 1.37, 5.43 | 1.47 | 0.65, 3.33 | 2.68 | 1.53, 4.69 |
| Pain interference (reference: no pain interference) | 1.65 | 1.01, 2.71 | 3.87 | 1.81, 8.28 | 1.95 | 1.08, 3.53 | 2.07 | 1.22, 3.51 |
| Perceived health status (reference: poor) | | | | | | | | |
| Excellent | 0.73 | 0.36, 1.50 | <0.01 | <0.01, >9.99 | 0.17 | 0.03, 0.95 | 0.33 | 0.13, 0.83 |
| Good | 0.93 | 0.53, 1.60 | 6.22 | <0.01, >9.99 | 0.76 | 0.36, 1.58 | 0.75 | 0.45, 1.23 |
| Fair | 1.01 | 0.67, 1.50 | 8.40 | <0.01, >9.99 | 2.02 | 1.02, 3.98 | 1.68 | 1.10, 2.56 |

Note: ADL=activities of daily living; 95% CI=95% confidence interval; OR=odds ratio; UWL=unexplained weight loss.

*Reference: No ADL disability at baseline and follow-up.

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## Table 1

Baseline Descriptive Characteristics of the Participants

| | Overall (n = 672) | Males (n = 238) | Females (n = 434) |
|---|---|---|---|
| Handgrip strength, kg | 20.8 ± 7.4 | 27.4 ± 6.9* | 17.2 ± 4.7 |
| Age, years | 81.7 ± 4.1 | 81.8 ± 4.2 | 81.6 ± 4.1 |
| Body mass index | 27.5 ± 5.0 | 26.9 ± 4.1* | 27.8 ± 4.1 |
| Lost 1ADL functions | 4.1 ± 1.7 | 3.9 ± 1.7 | 4.3 ± 1.7 |
| Lost ADL functions | 0.6 ± 1.2 | 0.5 ± 1.1 | 0.6 ± 1.2 |
| Stroke diagnosis, n (%) | 29 (4.3) | 12 (5.0) | 17 (3.9) |
| Previous falls, n (%) | 222 (33.0) | 61 (25.6)* | 161 (37.1) |
| Diabetes diagnosis, n (%) | 201 (29.9) | 66 (27.7) | 135 (31.1) |
| Diabetes medications, n (%) | 182 (90.5) | 62 (93.4) | 120 (88.9) |
| Physically inactive, n (%) | 95 (14.1) | 28 (11.8) | 67 (15.4) |
| Unexplained weight loss, n (%) | 125 (18.6) | 43 (18.1) | 82 (18.9) |
| Chronic exhaustion, n (%) | 145 (21.6) | 42 (17.7) | 103 (23.7) |
| Slow walking speed, n (%) | 111 (16.5) | 40 (16.8) | 71 (16.4) |
| Pain interference, n (%) | 339 (50.5) | 100 (42.0)* | 239 (55.1) |
| Perceived health status, n (%) | | | |
| Excellent | 41 (6.1) | 18 (7.6) | 23 (5.3) |
| Good | 190 (28.3) | 64 (26.9) | 126 (29.0) |
| Fair | 379 (56.4) | 140 (58.8) | 239 (55.1) |
| Poor | 62 (9.2) | 16(6.7) | 46 (10.6) |
| Married, n (%) | 275 (40.9) | 159 (66.8)* | 116(26.7) |
| Number of people living in household | 2.4 ± 1.6 | 2.6 ± 1.9* | 2.2 ± 1.4 |
| Depressed, n (%) | 257 (38.2) | 65 (27.3)* | 192 (44.2) |
| Hypertensive, n (%) | 456 (67.9) | 153 (64.3) | 303 (69.8) |
| Hypertension medication, n (%) | 436 (95.6) | 145 (94.8) | 291 (96.0) |

ADL, activities of daily living; IADL, instrumental activities of daily living.

*$P < .05$.

**Table 2**

Results for the Association Between Handgrip Strength and 2-Year Loss of IADL Function

| | OR | 95% C1 |
|---|---|---|
| Handgrip strength | 0.95 | 0.92, 0.98 |
| Baseline 1ADL function | 1.79 | 1.61, 1.99 |
| Age | 1.15 | 1.10, 1.19 |
| Body mass index | 1.02 | 0.99, 1.05 |
| Female (reference: male) | 1.00 | 0.66, 1.52 |
| Previous falls (reference: no falls) | 0.93 | 0.68, 1.28 |
| Diabetes (reference: no diabetes) | 1.45 | 1.04, 2.02 |
| Physically inactive (reference: active) | 1.62 | 1.03, 2.54 |
| Unexplained weight loss (reference: no unexplained weight loss) | 1.30 | 0.89, 1.90 |
| Chronically exhausted (reference: not exhausted) | 0.82 | 0.56, 1.21 |
| Slow walking speed (reference: not slow) | 0.60 | 0.39, 0.93 |
| Pain interference (reference: no pain interference) | 1.45 | 1.04, 2.04 |
| Perceived health status (reference: poor) | | |
| Excellent | 0.52 | 0.23, 1.19 |
| Good | 0.72 | 0.40, 1.28 |
| Fair | 0.80 | 0.48, 1.33 |

IADL, instrumental activities of daily living.

**Table 3**

Results for the Association Between Handgrip Strength and Changes in 2-Year ADL Disability Status

| | Onset ADL Disability* | | Persistent ADL Disability* | | ADL Disability Progression* | | ADL Disability Improvement* | |
|---|---|---|---|---|---|---|---|---|
| | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Handgrip strength | 0.92 | 0.88, 0.97 | 0.96 | 0.89, 1.04 | 0.88 | 0.83, 0.94 | 0.93 | 0.89, 0.98 |
| Age | 1.09 | 1.02, 1.16 | 1.19 | 1.08, 1.31 | 1.18 | 1.10, 1.28 | 0.99 | 0.92, 1.06 |
| Body mass index | 1.03 | 0.98, 1.08 | 1.05 | 0.97, 1.13 | 1.06 | 1.00, 1.13 | 1.02 | 0.97, 1.08 |
| Female (reference: male) | 0.80 | 0.40, 1.59 | 0.75 | 0.25, 2.23 | 0.68 | 0.29, 1.60 | 0.66 | 0.32, 1.32 |
| Previous falls (reference: no falls) | 0.80 | 0.47, 1.36 | 1.35 | 0.61, 3.01 | 0.76 | 0.40, 1.46 | 1.32 | 0.79, 2.21 |
| Diabetes (reference: no diabetes) | 1.47 | 0.87, 2.49 | 2.43 | 1.06, 5.54 | 1.32 | 0.67, 2.59 | 0.72 | 0.40, 1.27 |
| Physically inactive (reference: active) | 1.50 | 0.72, 3.13 | 1.87 | 0.71, 4.89 | 4.23 | 2.01, 8.89 | 1.87 | 0.91, 3.85 |
| Unexplained weight loss (reference: no unexplained weight loss) | 1.22 | 0.65, 2.29 | 0.70 | 0.24, 2.05 | 1.65 | 0.78, 3.05 | 1.85 | 1.03, 3.33 |
| Chronically exhausted (reference: not exhausted) | 1.35 | 0.75, 2.44 | 1.59 | 0.68, 3.74 | 0.41 | 0.18, 0.92 | 0.67 | 0.36, 1.25 |
| Slow walking speed (reference: not slow) | 0.66 | 0.31, 1.38 | 1.70 | 0.70, 4.10 | 0.62 | 0.26, 1.50 | 1.13 | 0.58, 2.21 |
| Pain interference (reference: no pain interference) | 1.75 | 1.02, 3.00 | 4.82 | 1.70, 13.65 | 3.49 | 1.70, 7.15 | 2.26 | 1.30, 3.94 |
| Perceived Health-Status (Reference: Poor) | | | | | | | | |
| Excellent | 0.41 | 0.09, 1.83 | 0.00 | 0.00, 0.00 | 0.11 | 0.01, 1.10 | 0.10 | 0.01, 0.89 |
| Good | 0.83 | 0.31, 2.19 | 0.62 | 0.16, 2.34 | 0.21 | 0.06, 0.70 | 0.34 | 0.12, 0.93 |
| Fair | 1.08 | 0.45, 2.62 | 0.76 | 0.25, 2.30 | 0.78 | 0.32, 1.89 | 1.00 | 0.44, 2.26 |

ADL, activities of daily living; 95% CI, 95% confidence interval; OR, odds ratio; UWL, unexplained weight loss.

*Reference: No ADL disability at baseline and follow-up.