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Prediction of Risk of Falling, Physical Disability, and Frailty by Rate of Decline in Grip Strength: The Women’s Health and Aging Study

Aging people progressively lose skeletal muscle mass and strength. Epidemiologically, a single measurement of grip strength has repeatedly proven to correlate with subsequent adverse health outcomes even when measured in midlife to predict physical disability decades later. This has led some to propose that grip strength be used clinically as an indicator of risk for decline in health, or even as a new “vital sign.” However, it remains unclear whether the risk of developing adverse outcomes is greater or less for a person who is relatively weak compared with other age-matched individuals than it is for a relatively strong person whose strength is declining rapidly. We hypothesized that those with a faster rate of decline would be at higher risk compared with those who had a weaker single grip measurement. We tested this hypothesis using longitudinal data from older women studied for the evolution of disability and functional decline with aging.

Methods. The Women’s Health and Aging Study (WHAS) II is an institutional review board–approved, prospective cohort study of 436 women aged 70 to 79 years with high functional ability at baseline, as previously described. Data were collected at baseline and 6 follow-up examinations approximately 18 months apart, except for the interval between the third and fourth examination, which was on average 3 years, resulting in a median follow-up time of 9 years (ranging from 1.5 to 13.3 years) between 1994 and 2008. The analytic sample for this report consisted of 352 women who had baseline data available on all covariates and had at least 2 measurements on grip strength during the follow-up period.

Grip strength was measured using a JAMAR hand dynamometer (Model #BK-7498; Fred Sammons Inc, Burr Ridge, Illinois). The maximum measurement of 3 trials in the nondominant hand was used in the analyses. Outcomes of the study included incident health events: falls, walking speed slower than 0.4 m/s, the WHAS frailty phenotype, and difficulty in 1 or more task (“disability”) of the Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) scales. We used a linear random effects model (REM) to assess population average rate of change in grip strength over time (ie, fixed effects) by including age in the model as a time-dependent covariate. To account for the observed nonlinear time trend in change of grip strength, a 2-piece linear spline was used in the REM with 1 knot fixed at age 75 years. To account for between-person heterogeneity in terms of individual deviation from the population mean trajectory, intercept (ie, grip strength at age 70 years, termed baseline strength henceforth) and age slope before age 75 years were modeled as random effects with an unstructured variance-covariance matrix.

Next, we performed joint analysis of the repeated measurements of grip strength and the time-to-event data using a method that has been previously published. The model assessed the effects of the rate of change in grip strength on the outcomes independent of baseline strength. For each outcome, analysis was restricted to women who were event-free at baseline and included only strength measurements up to the time of event onset or censoring. All analyses were adjusted for age, race, education, body mass index (BMI), number of chronic diseases, smoking status, physical activity, depressive symptomatology, and serum interleukin 6 and albumin, as in prior research. Statistical analyses were conducted in SAS (version 9.2; SAS Institute Inc, Cary, North Carolina).

Results. Of these 352 women included, 17% were African American and 70% were either overweight or obese. Their mean age was 74 years at baseline, with a mean 12.7 years of education. At baseline, 20% reported a history...
of falls in the past 12 months; 3% of women were frail; 11% and 5.4% reported any ADL and IADL disability, respectively; and none had a walking speed slower than 0.4 m/s.

The REM model estimated that the mean grip strength was 26.5 kg at age 70 years and declined an average of 1.08 kg/y between age 70 and 75 years (P < .001) and 0.52 kg/y thereafter (P < .001). Independent of baseline grip strength, a greater rate of decline in grip strength over time was significantly associated with higher risk for all outcomes except ADL disability. For example, the risk of developing an IADL disability was 1.32 times higher for every 0.5-SD unit (SD = 0.07 kg/y) increase in the rate of decline in grip strength (P < .001) after adjusting for age, race, education, BMI, and baseline strength. All results remained essentially unchanged after further adjustment for other covariates (Table).

Considering baseline grip strength, our analysis showed that higher baseline strength was significantly associated with a lower risk of IADL disability and frailty, but not the other outcomes, after adjusting for change in grip, age, race, education, BMI at baseline. Specifically, the risk of developing an IADL disability and becoming frail were 1.35 (P < .001) and 1.47 (P < .001) times higher, respectively, for every 0.5-SD unit (SD = 1.9 kg) decrease in baseline strength (Table).

Comment. We observed that a decline in grip strength over time is a stronger predictor of a greater variety of subsequent adverse outcomes compared with a single observation of grip strength, suggesting that “becoming weaker” is important in addition to “being weak.” These associations were independent of age, disease burden, life style, nutritional status, inflammation, and mental well-being. These results are congruent with the findings of prior cross-sectional studies. However, they offer further understanding of why weak grip is predictive of poor outcome, implying that at least some of the “risk attributable to weakness” seen in prior studies can be restated as “risk attributable to rate of losing strength” or perhaps “risk attributable to being in a strength-losing state.” This study suggests that measuring grip strength over repeated clinic visits may provide useful risk assessment information to patients, families, and clinicians. What most needs to be demonstrated to make grip strength more useful clinically, however, is whether it should trigger any specific interventions or diagnostic efforts. Until we know much more about the clinical relevance and underlying causes of change, it may be premature to promote grip strength—even its trajectory—as a “vital sign.”

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Table. Associations Between Decline in Strength and Incident Adverse Outcomes in WHAS II

<table>
<thead>
<tr>
<th>Variable</th>
<th>No.</th>
<th>HR (95% CI) Value</th>
<th>P Value</th>
<th>HR (95% CI) Value</th>
<th>P Value</th>
<th>HR (95% CI) Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>214</td>
<td>1.24 (0.99-1.55)</td>
<td>.06</td>
<td>1.40 (1.07-1.83)</td>
<td>.02</td>
<td>1.17 (0.98-1.41)</td>
<td>.09</td>
</tr>
<tr>
<td>Walking speed</td>
<td>348</td>
<td>1.21 (0.94-1.58)</td>
<td>.15</td>
<td>1.41 (1.09-1.83)</td>
<td>.01</td>
<td>1.21 (0.93-1.57)</td>
<td>.15</td>
</tr>
<tr>
<td>ADL disability</td>
<td>275</td>
<td>1.11 (0.89-1.40)</td>
<td>.35</td>
<td>1.39 (0.94-1.56)</td>
<td>.10</td>
<td>1.14 (0.91-1.43)</td>
<td>.24</td>
</tr>
<tr>
<td>IADL disability</td>
<td>320</td>
<td>1.35 (1.14-1.60)</td>
<td>&lt;.001</td>
<td>1.32 (1.13-1.54)</td>
<td>&lt;.001</td>
<td>1.35 (1.13-1.61)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Frailty</td>
<td>333</td>
<td>1.47 (1.22-1.77)</td>
<td>&lt;.001</td>
<td>1.34 (1.11-1.62)</td>
<td>&lt;.003</td>
<td>1.48 (1.22-1.80)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: ADL, Activities of Daily Living; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; HR, hazard ratio; IADL, Instrumental Activities of Daily Living; WHAS II, Women’s Health and Aging Study II.

a Results from survival analyses with grip strength at age 70 years and rate of change in grip strength over time being mutually adjusted for each other in all models.

b Total number of women who were event free at baseline and had complete covariate information and at least 2 grip-strength measurements before event onset or censoring.

c Incidence rate per 1000 person-years.

d Adjusted for age, race (white vs African American), education (grades completed), and BMI (categorized as <18.5, 18.5 to <25, ≥25 to <30, and ≥30).

e Adjusted for age, race, education, BMI, number of diseases (angina pectoris or myocardial infarction; congestive heart failure; peripheral artery disease; hip fracture; osteoarthritis of the hip, knee, or hand; Parkinson disease; rheumatoid arthritis; osteoarthritis; stroke; pulmonary disease; diabetes mellitus; cancer; spinal stenosis; and disc disease), smoking status (current smoker, former smoker, or never smoker), depressive symptomatology (<10 on the 30-item Geriatric Depression Scale), physical activity (0, 1-149, or ≥150 min/wk of moderate-intensity activities including walking for exercise, heavy household chores, heavy outdoor work, regular exercise, dancing, and bowling), albumin level, and interleukin 6 level.

f Numbers presented are HR estimates for a 0.5-SD unit increase in grip strength (1.9 kg) at age 70 years.

g Numbers presented are HR estimates for a 0.5-SD unit decrease in grip strength (1.9 kg) at age 70 years.

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Whereas atherothrombotic stroke accounts for approximately one-half of ischemic strokes in Western populations, in the Japanese population it accounts for only approximately one-quarter of ischemic strokes, and cardioembolic stroke was more common than atherothrombotic stroke, accounting for 31% to 38% of ischemic strokes. As reported herein, the association of total cholesterol level with total ischemic stroke mortality was examined in a cohort of the general Japanese population, in whom the risk for coronary disease is very low and atherothrombotic stroke accounts for a lower proportion of ischemic strokes.

Methods. In Moriguchi City, Osaka, Japan, any citizen 13 years or older who did not receive another annual health examination covered by the Occupational Health and Safety Law or the School Health Law could receive the examination supported by national and local governments. The examination was performed as a mass health screening-style program targeting citizens without medical problems or a primary physician. The study population comprised 16,461 subjects who had an annual health examination in 1997, when the data started to be archived. Because those who underwent the examination mainly included self-employed people and their dependents, retirees, and dependents of employees who were not offered the examination by the employees’ companies, women predominated among the study subjects.

The subjects were followed until the end of 2009. The cause of death was determined by the death certificates stored in the National Vital Statistics database sent from the Ministry of Health and Welfare. The underlying cause of death was coded according to the International Statistical Classification of Diseases, 10th Revision (ICD-10). Subjects who moved from Moriguchi City were treated as censored cases. The institutional review board of Kansei Medical University approved this study.

Hypertension was defined as a systolic blood pressure of 140 mm Hg or higher, diastolic blood pressure of 90 mm Hg or higher, or the use of antihypertensive agents. Diabetes was defined as a nonfasting plasma glucose level of 200 mg/dL or higher (to convert to millimoles per liter, multiply by 0.0555), a fasting plasma glucose level of 126 mg/dL, or a history of diabetes. Smoking included only current smokers. A drinking habit was considered to be present if the subjects answered that they drank often or more frequently on the interview questionnaire.

The association between total cholesterol level and mortality was determined by dividing the subjects into 4 groups. Total cholesterol levels of 160 mg/dL, 200 mg/dL, and 240 mg/dL (to convert to millimoles per liter, multiply by 0.0259) were used as cutoff points. The relative risks were calculated with 95% confidence intervals for each end point of each subgroup relative to the lowest cholesterol category (<160 mg/dL) using a proportional hazards regression analysis with adjustment for age, sex, current smoker (yes/no), hypertention (yes/no), diabetes (yes/no), drinking habit (yes/no), and history of cardiovascular disease (yes/no). The statistical significance level was set at .05 (2 sided).