Grip strength changes over 27 yr in Japanese-American men

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1Epidemiology, Demography, and Biometry Program, National Institute on Aging, National Institutes of Health, Bethesda, Maryland 20892; and 2Honolulu Heart Program, Honolulu-Asia Aging Study, Kuakini Medical Center, Honolulu, Hawaii 96813

Rantanen, T., K. Masaki, D. Foley, G. Izmirlian, L. White, and J. M. Guralnik. Grip strength changes over 27 yr in Japanese-American men. J. Appl. Physiol. 85(6): 2047–2053, 1998.—The aim of this study was to describe changes in grip strength over a follow-up period of ~27 yr and to study the associations of rate of strength decline with weight change and chronic conditions. The data are from the Honolulu Heart Program, a prospective population-based study established in 1965. Participants at exam 1 were 8,006 men (ages 45–68 yr) who were of Japanese ancestry and living in Hawaii. At follow-up, 3,741 men (age range, 71–96 yr) participated. Those who died before the follow-up showed significantly lower grip-strength values at baseline than did the survivors. The average annualized strength change among the survivors was −1.0%. Steeper decline (>1.5%/yr) was associated with older age at baseline, greater weight decrease, and chronic conditions such as stroke, diabetes, arthritis, coronary heart disease, and chronic obstructive pulmonary disease. The risk factors for having very low hand-grip strength at follow-up, here termed grip-strength disability (=21 kg, the lowest 10th percentile), were largely same as those for steep strength decline. However, the age-adjusted correlation between baseline and follow-up strength was strong (r = 0.557, P < 0.001); i.e., those who showed greater grip strength at baseline were also likely to do so 27 yr later. Consequently, those in the lowest grip-strength tertile at baseline had about eight times greater risk of grip-strength disability than those in the highest tertile because of their lower reserve of strength. In old age, maintenance of optimal body mass may help prevent steep strength decrease and poor absolute strength.

ag; muscle; prospective study; body composition; chronic diseases

WITH INCREASING AGE, muscle strength decreases and may eventually reach a level at which weakness starts to restrict the ability to perform usual activities (25, 36). In the very old, loss of muscle mass and strength are suggested to be important factors in the process of increased frailty (17). Most of the information about age-related strength changes is based on cross-sectional data (21). In previously published longitudinal studies, the participants have been a selected group of people, or the numbers have been small (1, 2, 12, 13), or the follow-up period has been fairly short (4).

Measurements made in large epidemiologic studies involving older participants have to be cost-effective for the researchers and not too burdensome to participants. Grip-strength tests are convenient, safe, and reliable, and they do not require large or expensive equipment (3, 28). Consequently, grip strength has been used as an indicator of overall muscle strength (4, 16). Use of grip strength as a feasible model to describe overall strength changes is supported by its significant (P < 0.001) correlations with other strength measures in older men [r = 0.638 for elbow flexion, r = 0.524 for knee extension, r = 0.515 for trunk extension, and r = 0.437 for trunk flexion (29)].

The Baltimore Longitudinal Study on Aging combined cross-sectional and longitudinal data. Hand-grip strength was found to increase up until the thirties and to start to decrease with accelerated speed after the forties (16, 23). Cross-sectionally, lower muscle strength was associated with lower muscle mass as measured by creatinine excretion (16). With aging, muscle mass is lost due to motoneuron death (23) and muscle cell shrinking due to inactivity (14). Also, hormonal changes, particularly decreases in testosterone and growth hormone levels, may be associated with muscle mass decrease (17). Diseases may cause decrease in strength through inactivity, or they may have a direct effect on muscle (4, 32). For example, in stroke, the injury in the central nervous system will affect the descending neural pathways and result in poor motor unit activation (22). However, great interindividual differences are evident in strength decline with increasing age. For example, Kallman et al. (16) found that over an average 9-yr follow-up period, 15% of the subjects ages 60 and over did not show any strength decline.

The aims of this study were 1) to describe the extent of change in grip strength over a follow-up period of ~27 yr in a large group of initially 45- to 68-year-old Japanese-American men (n = 8,006) living in Hawaii and 2) to study age, body weight changes, and morbidity as predictors of grip-strength change.

METHODS

The participants are from the Honolulu Heart Program and the Honolulu-Asia Aging Study which began in 1965. This program has been described earlier (35). Briefly, the World War II Selective Service Registration file was used to identify 12,417 possibly eligible men of Japanese ancestry (having a J Japanese last name and/or listed as of J Japanese origin) born from 1900 to 1919 and living in Oahu. These men were sent a questionnaire. In all, 1,269 men were not located, and 1,270 refused to answer the questionnaire. A further 1,692 men who answered the questionnaire refused to participate in the physical examinations, and 180 men who responded to the questionnaire died before they were
was converted into meters (BMI, respectively. To calculate body mass index (BMI), height exam 4.
The best result was chosen for analyses. In that case, that one result was chosen for the analyses.

Hand-grip strength was measured by using the Smedley Hand Dynamometer (Stoelting, Wood Dale, IL). While each participant was sitting, he extended his arm in front of him on the table and gripped the dynamometer. If necessary, the tester held the dynamometer steady. The width of the handle was adjusted, so that, when the subject held the dynamometer, the second phalanx was against the inner stirrup. Three trials, with brief pauses, were allowed for each hand alternately. Subjects were encouraged to exert their maximal grip. The best result was chosen for analyses.

Body weight and height were measured during exam 1 and exam 4, and values were expressed as kilograms and centimeters, respectively. To calculate body mass index (BMI), height was converted into meters (BMI = weight/height²).

In exam 1, the upper arm circumference and triceps skinfold were measured with the subject standing, arms relaxed, and arms hanging vertically at the side. Recordings were done to the nearest full millimeter. Upper arm circumference was measured by using a standard tape measure midway between the axilla and elbow, without applying excessive pressure. The skinfold thickness over the triceps muscle midway between the axilla and elbow was measured by using a Lange Skinfold Caliper (Cambridge Scientific Industries, Cambridge, MD). Longitudinal fold of skin and subcutaneous tissue was taken between the thumb and the forefinger without applying excessive pressure or traction. Caliper tips were applied 1 cm below the fingertips.

Upper arm lean area was estimated from upper arm circumference and triceps skinfold thickness as follows

\[ A_l = \frac{\pi}{4} \cdot \left( C/\pi - Str \right)^2 \]

where \( A_l \) is upper arm lean area, \( C \) is upper arm circumference, and \( Str \) is triceps skinfold.

The prevalence of angina pectoris, hypertension, coronary heart disease, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), diabetes mellitus, and arthritis was ascertained in exam 4. Presence of angina or arthritis was based on self-report ("Has a doctor ever told you that you have...?"). Hypertension was verified if blood pressure was \( \geq 160/95 \) mmHg or the participant was taking blood pressure medication. Three blood pressure measurements were done 5 min apart on the left arm of the seated subject with the use of a standard sphygmomanometer. The results were averaged. Diabetes was ascertained by asking subjects if they had a diagnosis of diabetes or if they used insulin or pills for diabetes, as well as with a help of a glucose tolerance test using the World Health Organization classification (31).

Coronary heart disease was verified on the basis of hospital record surveillance, electrocardiographic findings, and questionnaire data (18). Stroke prevalence was based on hospital record surveillance. COPD was judged on the basis of questionnaire data (cough and phlegm lasting \( \geq 3 \) mo consecutively or a physician’s diagnosis of emphysema).

Statistical Methods

Means according to age group strata (5-yr groupings) at baseline were compared by using a one-way analysis of variance. The differences in strength at baseline between survivors and nonsurvivors were studied by t-tests. Pearson's correlations were used to study the association among age, strength, and anthropometric variables. Age-adjusted associations between grip strength and anthropometric variables were analyzed by using partial correlations. Strength changes over the follow-up in age strata were studied by using t-tests for paired samples. Cross-tabulation with \( \chi^2 \) test was used to study the proportion of those with steep, average, and moderate strength decline in groups based on baseline age. Linear regression analysis was used to study age and weight change as predictors of rate of strength decline. Odds ratios (OR) for steep strength decline and grip-strength disability were computed by logistic regression analyses.

RESULTS

At exam 1, one-way analysis of variance showed that the older participants had significantly lower grip strength, body height, weight, BMI, and smaller \( A_l \) than the younger participants (Table 1). The age-adjusted correlations between baseline grip strength and anthropometric variables were as follows. Exam 1: body height, \( r = 0.441, P < 0.001 \); body weight, \( r = 0.401, P < 0.001 \); BMI, \( r = 0.229, P < 0.001 \); and \( A_l, r = 0.347, P < 0.001 \). The age-adjusted correlation between \( A_l \) and body weight was \( r = 0.520, P < 0.001 \).

Figure 2 shows grip strength according to age strata at baseline among those who survived follow-up measurements, among the nonsurvivors, and among the survivors at follow-up. At baseline, in all age groups, those who died before the follow-up examinations exhibited lower grip strength than did the survivors (\( P < 0.012 \)). However, in the nonsurvivors, the body weight was also on average 0.49 kg lower than in...
the survivors (\(P = 0.025\)). The intra-individual strength changes over time were significant in all age groups (\(P < 0.001\)). The age-adjusted correlation between baseline and follow-up strength was strong (\(r = 0.557\), \(P < 0.001\)), indicating that those who showed greater grip strength at baseline were also likely to do so 27 yr later. Among the survivors, the absolute grip-strength change was calculated as the difference between the baseline and follow-up strength was strong (\(P = 0.001\)), indicating that those who showed greater increase. For steep strength decline, those who lost \(\geq 5\) kg had OR of 3.24 and 95% confidence intervals (95% CI) of 2.44–4.33, whereas those who lost 4.99–0.01 kg of weight had OR of 1.51 and 95% CI of 1.09–2.09, respectively, compared with those who did not lose any weight.

Chronic diseases of participants were ascertained at exam 4 (Table 3). The bivariate OR for losing >1.5% of grip strength/yr (adjusted for age and baseline grip strength) were as follows: stroke (OR = 3.4; 95% CI, 2.37–5.01), arthritis (OR = 1.49; 95% CI, 1.14–1.95), diabetes (OR = 1.88; 95% CI, 1.48–2.38), coronary heart disease (OR = 1.49; 95% CI, 1.20–1.82), and COPD (OR = 1.83; 95% CI, 1.09–3.07). Angina and cancer were not significantly more common among those with steep strength decline. Hypertension, however, was protective of steep decline (OR = 0.71; 95% CI, 0.57–0.88).

Finally, we wanted to study the predictors of having very low muscle strength in old age, termed here grip-strength disability. Grip-strength disability was defined as the lowest 10th percentile of old-age grip strength, with the cut-off point being 21 kg. The age-adjusted bivariate OR values are shown in Table 4. The risk of becoming grip-strength disabled was about eight times greater among those who at baseline had grip strength in the lowest tertile and about two times

<table>
<thead>
<tr>
<th>Baseline Age Group, yr</th>
<th>n</th>
<th>Grip Strength, kg</th>
<th>Height, cm</th>
<th>Weight, kg</th>
<th>BMI, kg/m²</th>
<th>Arm Lean Area, cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>45–49</td>
<td>1,831</td>
<td>41.7 ± 0.13</td>
<td>162 ± 0.13</td>
<td>65.7 ± 0.21</td>
<td>24.3 ± 0.07</td>
<td>54.3 ± 0.25</td>
</tr>
<tr>
<td>50–54</td>
<td>2,792</td>
<td>40.1 ± 0.11</td>
<td>161 ± 0.11</td>
<td>64.2 ± 0.17</td>
<td>24.0 ± 0.06</td>
<td>53.3 ± 0.19</td>
</tr>
<tr>
<td>55–59</td>
<td>1,590</td>
<td>39.7 ± 0.04</td>
<td>160 ± 0.14</td>
<td>63.0 ± 0.22</td>
<td>23.7 ± 0.08</td>
<td>51.1 ± 0.25</td>
</tr>
<tr>
<td>60–64</td>
<td>1,334</td>
<td>35.3 ± 0.15</td>
<td>158 ± 0.15</td>
<td>60.6 ± 0.24</td>
<td>23.3 ± 0.08</td>
<td>48.1 ± 0.27</td>
</tr>
<tr>
<td>65–68</td>
<td>450</td>
<td>33.3 ± 0.24</td>
<td>157 ± 0.26</td>
<td>59.8 ± 0.43</td>
<td>23.1 ± 0.15</td>
<td>47.6 ± 0.41</td>
</tr>
</tbody>
</table>

Values are means ± SE; n, no. of subjects. BMI, body mass index.

Fig. 2. Mean grip strength (in kg) according to age at baseline among nonsurvivors and survivors and at follow-up 27 yr later among survivors. Survivors in 45- to 49-yr-old age group at baseline are same individuals as in 71- to 76-yr-old age group at follow-up.

Fig. 3. Absolute change in grip strength over 27 yr according to baseline age. Percentiles are shown in each age stratum.

Table 1. Baseline height, weight, BMI, upper arm lean area, and grip strength according to baseline age groups

Fig. 4. Grip strength change (kg) according to age at baseline among nonsurvivors and survivors.
greater for those in the middle tertile compared with those in the highest tertile at baseline. Participants in the lowest tertile in body height, body weight, and upper arm muscle area had approximately twice the risk compared with those in the highest tertile. The prevalence of arthritis, coronary heart disease, stroke, and diabetes was greater among those with grip-strength disability than among the rest of the participants. Hypertension, however, was protective of grip-strength disability. Weight change between exams 1 and 4 as the predictor of grip-strength disability is illustrated in Fig. 4. The participants were stratified into tertiles according to their weight in exam 1 to study whether weight loss would predict grip-strength disability differently in these tertiles. The reference group was those with exam 1 weight in the middle tertile and no weight decrease. Regardless of initial weight, those who lost $\geq 5$ kg had about five to six times the risk of grip-strength disability, even after adjusting for age, height, and baseline grip strength.

DISCUSSION

The aim was to study changes in muscle strength from middle to old age by using grip strength as the model. Altogether, 8,006 men (age 45–68 yr) participated in exam 1. At the end of the follow-up period (on average, 27 yr), 3,680 men (with ages that ranged from 71 to 96 yr) participated in grip-strength tests. No previous studies have presented strength data of a large group of people over such a long follow-up period.

The average annualized grip-strength decline was 1.0%/yr (SE 0.008). Earlier longitudinal studies have reported declines in average grip strength, ranging from 0.7 to 3%/yr (2, 4, 5, 28). The age groups, however, are not always comparable. In the present study, great interindividual variation in strength changes were found. Older people were more likely to show steeper decline than younger people. This result is consistent with previous studies (2, 4, 5, 16). In previous studies of people, ages 65 yr and older, with follow-up periods varying between 5 and 9 yr, the decreases become more pronounced after the 50s and 60s (16).

In previous studies of people, ages 65 yr and older, with follow-up periods varying between 5 and 9 yr,
Among the major sites for glucose disposal during carbohydrate loading, findings of a previous study (19) suggest that poor skeletal muscle strength, which is usually associated with lower levels of physical activity and less muscle mass, may precede and predict the development of insulin resistance. Insulin resistance is associated with the development of non-insulin-dependent diabetes mellitus. However, in the present study, the baseline grip strength or age did not differ between those who had or did not have diabetes at exam 4, but the follow-up grip strength was significantly (P = 0.001) lower among those with diabetes [28.5 ± 0.26 (SE) kg, n = 658] than those without diabetes [29.4 ± 0.12 kg, n = 3,184]. A probable explanation for steep strength decline among those with diabetes was neuropathy, which is a common complication of both insulin-dependent and non-insulin-dependent diabetes. Muscle weakness and atrophy are among the defects experienced by those with neuropathy (8).
Stroke was associated with steep strength decline and grip-strength disability, although the strength of the better, most probably the unaffected, hand was used in the analyses. Muscle weakness is one of the manifestations of impaired neurological function after stroke. Stroke patients have been found to have lower muscle strength also on the unaffected side (22) and to be physically more inactive than healthy controls (6).

Hypertension, however, was associated with lower risk of steep strength decline (OR 0.71; 95% CI, 0.57–0.88). A probable explanation for this is that body weight and grip strength are correlated, whereas higher body weight is a risk factor for hypertension. In the present study, those who had hypertension at exam 4 had greater body weight (P < 0.001) at exam 1 (64.2 ± 0.19 kg, n = 2,030) than those who were normotensive at exam 4 (63.3 ± 0.20 kg, n = 1,767). In addition, those with hypertension at exam 4 lost significantly (P < 0.001) less weight over the follow-up period (−2.01 ± 0.16 kg, n = 1,936) than those who did not have hypertension (3.02 ± 0.18 kg, n = 1,658). However, a further adjustment for body weight did not change the OR meaningfully. Exercise is commonly recommended to those with high blood pressure. Diagnosis of hypertension may make people more aware of their living habits and serve as an incentive for healthier lifestyle.

Diseases and weight loss are treated in these analyses as independent predictors of strength loss. Weight loss and morbidity are, however, related. In the Cardiovascular Health Study (15), those who lost >10% of their weight were more likely to report fair or poor health and mobility disability and to have more medications than those who maintained their weight.

The data in this study suggest that strength decreases at an increasing rate toward the higher age groups and that weight loss and chronic conditions, such as stroke, diabetes, arthritis, coronary heart disease, and COPD are associated with a steeper decline. Although these analyses were restricted to one ethnic and gender group, men with Japanese ancestry, the findings can probably be generalized to other populations. These physiological processes are unlikely to differ materially, for example, according to race. Weight loss in old age may predispose people into accelerated strength loss. Consequently, good disease management and maintenance of optimal weight may help prevent steep strength decline in older people.

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