Longitudinal changes in selected physical capabilities: muscle strength, flexibility and body size

E. J. BASSEY
School of Biomedical Sciences, University of Nottingham Medical School, Nottingham NG7 2UH, UK.
Fax: (+44) 0115 970 9259; E-mail: Joan.Bassey@nottingham.ac.uk

Abstract

Objectives: first, to record, in a representative sample of older men and women, longitudinal changes in (i) maximal voluntary strength of the handgrip muscles, (ii) maximal range of movement in the shoulder joint and (iii) body weight and skeletal size; second, to explore associations between the changes in muscle strength and both customary physical activity and health outcomes.

Design: longitudinal analyses of survivors measured at baseline, and 4-year and 8-year follow-ups.

Participants: 350 survivors of a random sample originally aged 65 and over.

Results: over 8 years average loss of body weight was slight but significant at about 2 kg (less than 5%). Loss of shoulder range was negligible, while loss of muscle strength was significant at about 40 N (less than 2% per year). Demispan remained stable across all three points of measurement. These mean values concealed substantial variation in the rate of loss of strength, which was twice as fast in the older groups, especially in the women. These losses could not be attributed to worsening health, although this was observed. All the respondents had at least two chronic health problems at the 8-year stage. For the changes in handgrip strength, reduced reported habitual use of the handgrip muscles and increased symptoms of anxiety and depression were significant independent covariates in addition to age and time (all $P<0.0001$).

Conclusion: there are significant independent associations between the loss of muscle strength in old age and both decline in physical activity and increase in depression scores. This is strongly suggestive of causal links and confirms the need to encourage physical activity and control depression in order to maintain strength and function in old age.

Keywords: ageing, customary activity, elderly, handgrip strength, health outcomes, shoulder range

Introduction

While the maintenance of physical capabilities is essential for continuing independence in old age, there have been few longitudinal studies in this area [1]. Measurements of muscle strength, flexibility and body size were therefore included in the Nottingham Longitudinal Study (NLSAA) in order to obtain normative descriptions and to explore their associations with activity and health.

Old age is associated with inevitable time-dependent losses in physical capabilities. However, falling levels of customary physical activity are suspected to contribute substantially to these losses as well as deterioration in physical and mental health. In the present paper these hypotheses are explored in a group of 350 longitudinal study survivors, all aged over 73 years at the final survey.

Choice of physical capabilities

Choice of measurement was limited by practical issues in a house-to-house survey but was influenced by functional relevance as well as feasibility. Portable equipment was used to measure four variables: maximal isometric strength of the power grip of the hand, maximal range of movement of the shoulder joint in abduction in 45° of flexion, body weight and demispan (a linear dimension of skeletal size).

Handgrip strength, which has been used as a marker for muscle strength in general [2] and is significantly associated with a reduced incidence of falls, may be a
marker for good locomotor capability [3]. Handgrip is a measure of the power grip of the hand which is used for lifting and as an adjunct to leg strength when rising from a low chair, getting on to a bus or out of the bath. This grip depends on the muscles of the forearm and, since the grip forms a closed system of forces, it can be measured without the heavy stabilizing equipment needed to measure other muscular actions such as knee extension.

Adequate range of movement in the shoulder joint is needed for reaching above the head to get items down from high shelves, draw curtains, or hang out washing and also for reaching the back of the neck to fasten clothes and brush hair. Loss of range in this joint is common in old age and contributes to difficulties with the necessary tasks of independent living [4].

Body weight and skeletal size are basic body dimensions which influence muscle strength. Larger people are stronger, other factors being equal. Skeletal size was assessed using demispan (the distance between the finger roots and the sternal notch) because height is sometimes invalidated in old age by kyphotic changes in the spine.

Cross-sectional analyses of the initial data and a 4-year follow-up of these objective variables and their associations with activity and health have been reported [5-7]. This paper will therefore deal mainly with the changes in handgrip and shoulder range for the survivors at eight year follow-up, and explore possible associations between any changes found in these primary variables and other independent potentially explaining variables, such as falling health and customary activity.

### Methods

The methodology and longitudinal conduct of the study has been reported in detail elsewhere [8], and so will be described only briefly here.

#### Objective measurements

The interviewers were trained to use the equipment and apply the standardized techniques within a 2-week training period which preceded field data collection. All the interviewers were required to assess a group of 10 people of varying size on two occasions so that inter- and intra-interviewer errors could be estimated.

Handgrip strength was measured using a specially designed strain-gauged dynamometer [5, 9]. The strain gauges provided a signal proportional to the force applied across the handset. The handset was calibrated regularly. The design was such that the force registered was not affected by the position of force application along the bar. Among old people, arthritis or deformation of the hand from other causes may cause significant variation in the patterns of force application. The bars of the handset were encased with moulded plastic for comfort. The best value out of three maximal attempts from the right hand was used as the definitive measurement. Visual feedback and strong verbal encouragement were provided. The coefficient of variation on retest was ±9% [10].

To assess shoulder joint movement, the maximal range of abduction in 45° of flexion [11] was measured using a gravity-operated goniometer (Myrhin, Ob, Stockholm). This is the natural plane of movement of the arm in the shoulder socket. The movement was made with the elbow extended and began with the arm hanging at rest by the side. The arm was then swung upwards and outwards on a path half-way between the frontal and sagittal planes. The measurement was made on the left side, unless this shoulder had been injured, with the subject standing. The best of at least two satisfactory measurements was used provided they were within 5% of each other. The coefficient of variation on retest was ±5%.

Body weight was measured without shoes in light indoor clothing using calibrated bathroom scales from Krups (Ireland) which were precise to ±0.5 kg (range 0-130 kg). The scales were calibrated initially and checked regularly. The coefficient of variation was less than 1%.

Skeletal size was assessed using demispan which is the distance between the finger roots and the sternal notch when the arm is fully outstretched in line with the shoulders [12]. It was measured by a single observer using a flexible metal tape. This was supplied with buttons to keep the 0 mark exactly at the root of the middle and ring fingers whilst the observer kept the arm in line with the shoulders and stretched the tape to the notch. The coefficient of variation was less than 1%.

#### Questionnaire data

Health outcomes included in the current analyses included: the NLSAA health index score (derived from a 14-item symptom check list), the Life Satisfaction Index (LSI), the Brief Assessment of Social Engagement (BASE), the Symptoms of Anxiety and Depression (SAD) scale and current perceived health status (from poor to excellent) on a five-point scale. In addition those reporting 'pain at night and stiffness in the morning' were identified as suffering from arthritis [13].

Time (in min) spent per week in indoor, outdoor and leisure pursuits was cumulated to form a general activity index. Specific activities relevant to shoulder range and handgrip strength were also recorded on a five-point scale for frequency of occurrence, yielding a reaching high score and an effort score respectively [5, 14].
Table 1. Mean values for objective measurements for men and women

<table>
<thead>
<tr>
<th>Group/measurement</th>
<th>Men (n = 126)</th>
<th>Women (n = 221)</th>
<th>Change</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>8-year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.8 ± 11.2</td>
<td>71.0 ± 12.2</td>
<td>-1.7 ± 5.4</td>
<td>0.001</td>
</tr>
<tr>
<td>Demispan (cm)</td>
<td>81.7 ± 3.9</td>
<td>81.5 ± 4.3</td>
<td>-0.2 ± 2.9</td>
<td>0.55</td>
</tr>
<tr>
<td>Handgrip (N)</td>
<td>364 ± 79</td>
<td>315 ± 109</td>
<td>-48 ± 99</td>
<td>0.0001</td>
</tr>
<tr>
<td>Shoulder range (°)</td>
<td>130 ± 14</td>
<td>128 ± 27</td>
<td>-1.8 ± 27</td>
<td>0.46</td>
</tr>
</tbody>
</table>

|                   | Initial      | 8-year          |        |    |
| Weight (kg)       | 63.8 ± 12.6  | 60.9 ± 12.0     | -2.5 ± 6.5 | 0.0001 |
| Demispan (cm)     | 73.7 ± 3.4   | 73.7 ± 5.3      | 0.2 ± 2.5 | 0.82 |
| Handgrip (N)      | 212 ± 58     | 175 ± 69        | -37 ± 66 | 0.0001 |
| Shoulder range (°) | 122 ± 19     | 118 ± 31        | -4.8 ± 29 | 0.02 |

*Probability for changes (Student's t-test for paired means).

Analysis

Data from men and women were analysed separately throughout. Data are presented as means ± 1 SD unless otherwise stated. Changes and differences were evaluated using Student’s t-tests and Mann–Whitney or Wilcoxon tests if the data were ordinal or skewed. Simple associations were assessed using Pearson’s product moment correlation (r) and Spearman’s rank correlation (ρ) if the data were ordinal or skewed. Analysis of variance for repeated measures was used to explore whether changes in reported health and activity were significant independent covariates for the changes in the objective measurements (Super-nova, Cherwell, Oxford).

The initial, 4-year and 8-year data for handgrip strength were entered as a dependent compact variable; other independent factors found to be significant or nearly so in simple correlation were then added as covariates in stepwise fashion and kept in the model if they added significantly to the explained variance. All P values are two-tailed and reported as significant at less than 0.05.

Results

Of the survivors assessed at 8-year follow-up 347 (221 women and 126 men) were able to comply with the measurements. This was 85% of the 410 who responded. In addition, 11 women and two men were unable to stand and so were not assessed for shoulder range and weight. Mean ages for the group of 347 at the 8-year follow-up were 81.2 ± 5.1 (range 73–100) and 79.9 ± 4.6 (range 73–91) for women and men respectively. The pattern of change in handgrip strength was similar for the right and left hands so the results for the right hand, which was stronger, will be reported. The longitudinal changes over 8 years in survivors were similar in men and women (see Table 1 and Figure 1). Demispan was stable in both men and women. Body weight fell slightly but significantly. Changes in shoulder joint range were negligible. Handgrip strength deteriorated significantly in both men and women by a similar amount but in women the loss was greater in those initially aged over 75 years (22% compared to 10% in the younger half of the original age stratification). The number of health problems increased from three to five in men and from five to seven in women. This indicates a substantial loss of health. The prevalence of arthritis was 40% in men initially and did not
Table 2. Product moment correlation coefficients between the 8-year changes in grip strength as dependent and the changes in health and activity as independent variables

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r$</td>
<td>$P$</td>
<td>$r$</td>
<td>$P$</td>
</tr>
<tr>
<td>Age</td>
<td>-0.16</td>
<td>0.07</td>
<td>-0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Health index</td>
<td>-0.18</td>
<td>0.04</td>
<td>-0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Body weight</td>
<td>0.21</td>
<td>0.02</td>
<td>0.06</td>
<td>0.54</td>
</tr>
<tr>
<td>Effort score</td>
<td>0.07</td>
<td>0.45</td>
<td>0.19</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>General activity</td>
<td>0.04</td>
<td>0.65</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>SAD</td>
<td>0.13</td>
<td>0.14</td>
<td>-0.24</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LSI</td>
<td>0.06</td>
<td>0.52</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>BASE</td>
<td>0.17</td>
<td>0.05</td>
<td>0.15</td>
<td>0.02</td>
</tr>
</tbody>
</table>

BASE, Brief Assessment of Social Engagement; LSI, Life Satisfaction Index; SAD, Symptoms of Anxiety and Depression.

change. In women it was higher initially at 57% but dropped slightly to 48% at 8 years. It is unlikely therefore that loss of muscle strength or joint range could be attributed to this particular disease.

SAD did not change but the LSI and BASE fell significantly by about 1 point (20%) on average in men and women. The changes in these three indices were significantly related to each other in men and women but to changes in the health index in women only.

General physical activity scores decreased substantially from a median value of 960 to 355 min per day in men and from 840 to 415 in women. Reported use of handgrip (effort score) also declined by about 20% from a mean score of 2.0 to 1.8 in men and from 1.9 to 1.6 in women.

Reported use (reaching score) however showed no decrease; mean scores improved slightly in men (1.8 to 2.2) and did not change in women (1.6 to 1.6).

Changes in the two activity variables (general activity and effort score) were highly correlated as expected

but independent of the changes in the health index and psychological health scores, with the exception of changes in the effort score and BASE in men.

Simple correlations between the 8-year changes in strength, as the dependent variable, and changes in health and activity as independent variables are shown in Table 2. Changes in health and in weight were the most significant for men but changes in the SAD and effort scores for women. In order to take advantage of the three time points of measurement, and to combine the influence of independent variables, analysis of variance for repeated measures was then applied; the results are given in Table 3. In this analysis, age, effort and SAD scores were significant covariates in both men and women with the addition of body weight in men. In men the health index had a borderline effect but it was not independent of SAD and effort and did not improve the overall explained variance.

Changes in shoulder range in women were related to age and to changes in grip strength, demispan and general activity but not to the reaching score. In men they were related to changes in demispan and BASE but not to the reaching score. The changes in shoulder range were so small that they and their associated variables were not explored further.

Discussion

This longitudinal survey of survivors from an initially representative sample included substantial numbers of both men and women, with an average age of 80 years at the final follow-up. The data are therefore unique for England. The results showed that over 8 years on average in both men and women there was little or no loss of body weight or shoulder range and a rather modest loss of muscle strength of less than 2% per year which was similar in men and women. The mean values concealed substantial variation, which was greater than could be attributed to retest variation so the influence of covariates was worth exploring.

The strongest association with change in shoulder range was the change in demispan in both men and women, which was probably caused by musculo-skeletal problems affecting both measurements in a small number of people. Demispan was stable in the majority. The change in strength in women, who are much weaker than men, apparently also contributed to the reduced range of movement.

The age range was wide and the rate of loss in muscle strength was twice as fast in the older women; this confirms similar findings at 4 years [5]. Women have less absolute muscle strength than men at all ages which cannot be entirely accounted for by smaller body size and the data confirm this.

It was also clear that some individuals in the younger half of the age distribution improved in strength.

Table 3. Repeated measure analysis of variance of measurements in survivors at 0, 4 and 8 years; grip strength as the dependent variable

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$ ratio</td>
<td>$P$</td>
<td>$F$ ratio</td>
<td>$P$</td>
</tr>
<tr>
<td>Age</td>
<td>23.0</td>
<td>0.0001</td>
<td>58</td>
<td>0.0001</td>
</tr>
<tr>
<td>Effort score</td>
<td>7.0</td>
<td>&lt;0.01</td>
<td>23</td>
<td>0.0001</td>
</tr>
<tr>
<td>SAD score</td>
<td>10.0</td>
<td>0.001</td>
<td>19</td>
<td>0.0001</td>
</tr>
<tr>
<td>Body weight</td>
<td>33.0</td>
<td>0.0001</td>
<td>1.3</td>
<td>0.25</td>
</tr>
<tr>
<td>Time</td>
<td>8.0</td>
<td>&lt;0.001</td>
<td>15</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

SAD, Symptoms of Anxiety and Depression.
Several studies have confirmed that even in very old age muscle strength can be improved with extra use and effort [15, 16]. The association between muscle strength and effort scores which describe use of this muscle group has been found consistently: in the first cross-sectional analysis, in the 4-year follow up and now in this 8-year follow-up. This is consistent with other longitudinal studies which showed that if activity levels were maintained and no serious health problems developed then the loss of physical capabilities was slight [17–19]. However these studies were in selected groups of men, whereas in this representative survey it was in the women that evidence of the influence of maintained use was found most strongly.

In the men there was an association between changes in muscle strength and in body mass despite the fact that it changed so little over the 8 years. This is consistent with loss of muscle mass provided fat mass remains constant. However, in women the association was not found, and in men the change in weight was not related to change in activity levels, effort score or health which might be expected.

The lack of influence of physical health was unexpected considering that all of the participants had at least two chronic health problems at this stage. The health index is a count of the number of different health problems suffered; it does not assess the severity of disease which may be getting worse. Nevertheless an average increase of two more health problems constitutes a substantial worsening of health.

The relations between changes in muscle strength and other changes were weak but this was expected since the retest variation in most of these measurements was large compared to the size of the differences observed. Many of the assessments are subjective estimates rather than precise objective measurements and are point samples taken to represent longer term conditions. The significance of the associations found is therefore impressive but it arises from the size of the data set and does not imply that predictions could be made. Rather, some insight into the network of interacting variables in a representative group is provided. The direction of cause and effect cannot be established without intervention but the results confirm that it is worthwhile to encourage activity and muscle use in old age and also to control symptoms of anxiety and depression.

References


