Normative Data for Grip Strength of Elderly Men and Women

Johanne Desrosiers, Gina Bravo, Réjean Hébert, Élisabeth Dutil

Key Words: aging • assessment process, occupational therapy

Objectives. Grip strength is an important prerequisite for good performance of the upper limb, hence it is important to evaluate it correctly. However, one of the main difficulties in evaluating the grip strength of elderly patients is the absence of valid norms. Therefore, the objective of this study was to develop normative data for maximum grip strength of persons aged 60 years and older.

Method. The grip strength of 360 subjects aged 60 years and older, randomly recruited by age and gender strata, was evaluated with the Jamar dynamometer and the Martin vigorimeter according to the protocol of the American Society of Hand Therapists.

Results. Grip strength diminishes curvilinearly with age, and men are consistently stronger than women. The data are presented by the means, standard deviations, and range, and as predictive equations obtained by regression analysis. In addition to age and gender, hand circumference and body height proved to be the best indicators of grip strength for this population of elderly subjects.

Conclusion. The random recruitment of subjects, the high participation rate in the study, and the comparability of the subjects who agreed to participate and those who refused give this study the high external validity that is essential to any norm study. The predictive equations will help occupational therapists to better estimate the expected grip strength of elderly patients than they could if using only age and gender.

Upper limbs play an important role in everyone’s daily life. A number of sensorimotor parameters, including grip strength, are necessary for their optimal performance. Grip strength is frequently evaluated in clinical settings as an indicator of disease activity (Rhind, Bird, & Wright, 1980). It has also proved to be a prognostic indicator of mortality risk in a population of elderly hospitalized women (Phillips, 1986). In addition to being an economical measure that is easy to administer, grip strength is one of the best indicators of the overall strength of the limb (Rice, Cunningham, Patterson, & Rechnitzer, 1989). Grip strength is evaluated as a component of hand function (American Society of Hand Therapists, [ASHT] 1992; Dent, Smith & Caspers, 1985; Jones, 1989).

The Jamar™ dynamometer1 and the Martin vigorimeter2 are well known for measuring grip strength. The Jamar™ dynamometer consists of a sealed hydraulic system with a sensitive gauge calibrated in pounds and kilograms. It is considered to be the most precise instrument for measuring grip strength (ASHT, 1992; Fess, 1987; 1Manufactured by Therapeutic Equipment Corporation, 60 Page Road, Clifton, NJ 07012. 2Manufactured by Gebruder Martin, Ludwigstrasse 132, Pouchach 60, D-7200 Tutlingen, Federal Republic of Germany.)
Kirkpatrick, 1956; Mathiowetz, Weber, Volland, & Kashi­
man, 1984; Schmidt & Toews, 1970). Mathiowetz et al.
(1984) reported that the mean of three trials has the
highest test–retest reliability (Pearson product–moment
 correlation coefficients: 0.89 for the right hand and 0.93
for the left) compared with only one trial (0.79 and 0.86).
The test–retest reliability of the highest score on three
trials is also high (0.82 for the right hand and 0.92 for the
left). No learning effect or fatigue is present when three
consecutive measures are taken (Mathiowetz, 1990).

The Martin vigorimeter consists of a rubber bulb
connected by a tube to a manometer; measures are ex­
pressed in kiloPascals (Agnew & Maas, 1991; Fike & Rou­
sseau, 1982; Giles, 1984). It is particularly recommended
for and used with persons with arthritis to avoid increas­
ing stress on joints that are already weak or painful
(Helewka, Goldsmith, & Smythe, 1981; Melvin, 1977). Un­
lke the Jamar™ dynamometer, the Martin vigorimeter
involves isotonic muscular action because of the move­
ment needed to compress the bulb. Jones et al. (1991) de­
monstrated the stability of Martin vigorimeter mea­
sures with high test–retest reliability (intraclass correla­
tion coefficients of 0.96 for the mean of three measures
on the dominant hand and 0.98 on the other).

Over the last 20 years and more, researchers have
developed normative reference values for grip strength
based on convenience samples. Kellor, Frost, Silberberg,
Iversen, and Cummings (1971) were among the first to
develop grip strength norms by using the Jamar™ dyna­
rometer with a sample aged 20 to 84 years. These norms
are still used in some clinical settings in spite of the lack of
standardization in the data collection procedure. Because
of this limitation, Mathiowetz et al. (1985) developed new
norms based on data obtained with a convenience sample
of 928 volunteers of both genders aged from 18 years to
94 years. These norms are more valid than those of Kellor
et al. (1971) because of the standardization in the data
collection procedure. However, Flood-Joy and Mathi­
ower (1987) reported the incorrect calibration of one of
the instruments used in developing the norms. This in­
correctly calibrated instrument would have been used
with 25% of their subjects, especially those aged 50 and
older. The main tendency would have been to underesti­
mate the performance of the subjects. Because of these
technical problems, there are currently no valid norms for
grip strength measured with the Jamar™ dynamometer
for people aged 60 and older.

Normative reference values have also been de­
veloped for the three sizes of bulbs in the Martin vigorimeter
with right-handed subjects aged 20 to 79 years who had
different occupations and showed no evidence of impair­
ment in the upper limbs (Fraser & Benten, 1983). How­
ever, the groups that were stratified according to age and
gender are very small (n = 10 per group). Another norms
study for the Martin vigorimeter was done with 450 ran­
domly selected subjects aged 21 to 65 years; it used the
large bulb for men and the medium one for women (Thor­
gren & Werner, 1979).

Except for the latter study, these normative studies
were done with convenience samples that might not be
representative of the targeted population because of the
recruiting methods. Another important limitation of the
current norms for elderly persons using the Jamar™ dyna­
rometer and the Martin vigorimeter is the small number
of very old subjects (older than 80 years of age) included
in the studies. The norms obtained by Mathiowetz et al.
(1985) categorized the subjects aged 75 years and older
into a single group; no subjects older than 80 years were
included in the norm study done by Fraser and Benten
(1983). It is difficult to assume that the performance of an
85-year-old is the same as that of a 75-year-old.

In addition to age, many factors may influence grip
strength: upper extremity position (Balogun, Akomolafe,
& Amusa, 1991; Kuzala & Vargo, 1992), physical activity
practice (Grinby, 1986), handedness or sidedness (Peter­
sen, Patcek, Cotowor, & Conklind, 1989), intramuscular
 temperature (Johnson & Leider, 1977), motivation (Lenn­
marken, Bergman, Larsson, & Larsson, 1985), and time of
day (Pearson, Mackinnon, Meek, Myers, & Palmer, 1982).

Body and hand anthropometrics are also important fac­
tors to consider. Many studies demonstrated significant
relationships between anthropometry and grip strength.
In most of these studies, weight was the variable most
related to strength (Chatterjee & Chowdhuri, 1991; Ever­
ett & Sils, 1952; Lunde, Brewer, & García, 1972), followed
by hand width, body height, hand length, and finger
length (Everett & Sils). However, Bassey & Harriss’ works
(1993) indicated that body height is the variable most
related to grip strength.

The goal of the present study was to develop norma­tive
reference values for maximum grip strength mea­
sured with the Jamar™ dynamometer and the Martin vi­
gorimeter for persons aged 60 years and older on the
basis of a randomly recruited sample.

Method

Subjects

A random sample of 360 subjects aged 60 years and older,
stratified for age (60–69 years, 70–79 years, and 80 years
and older) and gender, was drawn from the electoral list
of the city of Sherbrooke in Quebec, Canada, located 100
miles east of Montreal. Sherbrooke has a population of
76,000, nearly 17% of whom are older than 60 years of
age. Each subject was first contacted by mail and then by
telephone to verify eligibility criteria and willingness to
participate in the study. The eligibility criteria were lucid­
ity, independence in activities of daily living, sufficient
vision, and absence of any impairment affecting upper
limb function. When a subject refused or was not eligible,
another subject was selected until 60 subjects per stratum
were reached. Persons who refused to participate in the

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study even though eligible were asked to reply to a general information telephone questionnaire in order to estimate refusal bias. Questions covered age, hand dominance, height, weight, current activity level, and self-perceived health. Each subject was evaluated at the Upper Limb Function Measurement Laboratory at the Centre de recherche en gériatricie et gériatricie of the Hôpital D'Youville de Sherbrooke in Quebec. This study was part of a more comprehensive research on upper extremity performance of elderly men and women aged 60 years and older.

Procedure
Subjects were seated on a standard height chair without armrests. Anthropometric data (body weight, body height, hand length, hand circumference) were collected first. Hand circumference was measured at the thumb commissure following the axis of the head of the metacarpals; hand length was measured from distal crease of the wrist to the tip of the middle finger. A structured interview quantified other variables potentially related to strength, such as hand dominance (right-handed, left-handed, ambidextrous), previous or current work characteristics (active vs. sedentary, high use vs. low use of upper extremities, high vs. low upper extremity strength required, high vs. low fine dexterity required), self-perceived health (excellent, good, fair, poor), current activity level (very active, active, slightly active, sedentary), and frequency of current manual activities (very often, often, sometimes, seldom or never). Dominance was estimated with the Edinburgh Handedness Inventory (Oldfield, 1971).

Three grip strength measures of each hand were taken with the Jamar™ dynamometer and the Martin vigorimeter with a rest of about 30 sec between each. Contrary to the ASHT's recommendation, the highest score on these three trials was retained. Both hands were tested; the dominant hand was tested first. Measures were first collected with the Jamar™ dynamometer (Model 1) and then with the Martin vigorimeter. Occupational therapists collected data following Mathiowetz's instructions (Mathiowetz et al., 1984) and the ASHT (1992) recommendations concerning upper extremity position: shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position, and wrist in slight extension (0° to 30°). Calibration of the Jamar™ dynamometer was verified according to Fess' recommendations (Fess, 1987) before and during the study. Calibration of the vigorimeter was not verified. The Jamar™ dynamometer was set at the second handle position; the large bulb of the Martin vigorimeter was selected for all subjects.

Data Analysis
The characteristics of the study sample are described by the mean, the standard deviation, and the range for continuous variables and by frequency and percentage for categorical variables. T tests and chi square statistics were used to compare persons who participated in the study with those who refused.

The grip strength results are first presented by age group and gender in the form of means, standard deviations, and minimum and maximum values. These values are also presented through regression equations that relate strength to age. A 95% confidence interval around the predicted value is reported, to take sample variation into account. Multiple regression analyses were done to determine which variables might best explain grip strength and thus increase precision of estimates. With the object of simplifying clinical use, the predictive equations are reported according to gender and side, avoiding interaction terms. In order to avoid overestimating the real adjustment in the population, the adjustment measure in the prediction models considers the number of variables (adjusted $R^2$). The assumptions underlying the regression analysis were verified by residual analysis.

Results
Stratifying the 360 subjects by age and gender resulted in 60 men and 60 women in each age group, with the exception of women aged 60 to 69 years ($n = 59$) and men of the same age ($n = 61$) (see Table 1). The age of the women and men is equivalent across all groups with a mean age of 73.9. As expected, the anthropometric variables are higher among the men than the women (and the large majority of subjects are right-handed (92%). Most of the subjects did physically active work (83%) that required great use of the upper limbs (84%) but little strength (63%) and fine dexterity (74%). They described themselves as being in excellent or good physical health (84%) compared with others their age. Seventy-five percent of the subjects considered themselves to be active or very active. Because of the small number of subjects who are not right-handed, the results were analyzed without considering dominance.

The participation rate in the study was 78% (74% for women and 82% for men). Statistical analyses ($t$ tests or chi square) revealed no difference between those who refused and those who accepted in terms of age ($p = 0.06$), height ($p = 0.06$), weight ($p = 0.11$), dominance ($p = 0.83$), self-perceived health ($p = 0.19$), and current activity level ($p = 0.23$).

As expected, the men were consistently stronger than the women ($p < 0.0001$) (see Table 2). Grip strength diminished with increasing age (women: $r = -0.37$ to $-0.47$ and men: $r = -0.55$ to $-0.60$, depending on the hand and the instrument; $p < 0.0001$). This loss in strength was accentuated among the subjects aged 80 years and older (negative curvilinear relationship existed between grip strength and age). The right hands of the
Table 1

Descriptive Data of Study Subjects

<table>
<thead>
<tr>
<th>Variables</th>
<th>Women (n = 179)</th>
<th>Men (n = 181)</th>
<th>Total (n = 360)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>74.1 (8.2)</td>
<td>73.3 (7.8)</td>
<td>73.9 (8.0)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.8 (12.1)</td>
<td>65.0 (11.7)</td>
<td>62.9 (11.5)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>156.4 (6.8)</td>
<td>152.8 (6.7)</td>
<td>154.0 (6.8)</td>
</tr>
<tr>
<td>Hand size (cm)</td>
<td>17.2 (0.9)</td>
<td>16.4 (1.0)</td>
<td>16.8 (1.0)</td>
</tr>
<tr>
<td>Hand circumference (cm)</td>
<td>19.4 (1.1)</td>
<td>17.5 (1.2)</td>
<td>18.5 (1.2)</td>
</tr>
<tr>
<td><strong>Categorical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>169 (91.4)</td>
<td>161 (89.0)</td>
<td>330 (91.7)</td>
</tr>
<tr>
<td>Left</td>
<td>8 (4.5)</td>
<td>14 (7.7)</td>
<td>22 (6.1)</td>
</tr>
<tr>
<td>Ambidextrous</td>
<td>2 (1.1)</td>
<td>6 (3.3)</td>
<td>8 (2.2)</td>
</tr>
<tr>
<td>Previous or current work characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>158 (88.8)</td>
<td>139 (76.8)</td>
<td>297 (82.7)</td>
</tr>
<tr>
<td>Sedentary</td>
<td>20 (11.2)</td>
<td>42 (23.2)</td>
<td>62 (17.3)</td>
</tr>
<tr>
<td>High upper extremity strength</td>
<td>60 (33.7)</td>
<td>74 (40.9)</td>
<td>134 (37.3)</td>
</tr>
<tr>
<td>Low upper extremity strength</td>
<td>118 (66.3)</td>
<td>107 (59.1)</td>
<td>225 (62.7)</td>
</tr>
<tr>
<td>High use of upper limb</td>
<td>167 (93.8)</td>
<td>134 (74.4)</td>
<td>501 (84.1)</td>
</tr>
<tr>
<td>Low use of upper limb</td>
<td>11 (6.2)</td>
<td>46 (25.6)</td>
<td>57 (15.9)</td>
</tr>
<tr>
<td>High fine dexterity</td>
<td>59 (33.1)</td>
<td>35 (19.4)</td>
<td>94 (26.3)</td>
</tr>
<tr>
<td>Low fine dexterity</td>
<td>119 (66.9)</td>
<td>145 (80.6)</td>
<td>264 (73.7)</td>
</tr>
<tr>
<td>Self-perceived health</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>57 (31.9)</td>
<td>66 (36.5)</td>
<td>123 (34.2)</td>
</tr>
<tr>
<td>Good</td>
<td>85 (48.0)</td>
<td>92 (50.8)</td>
<td>177 (49.5)</td>
</tr>
<tr>
<td>Fair</td>
<td>34 (19.0)</td>
<td>18 (9.9)</td>
<td>52 (14.4)</td>
</tr>
<tr>
<td>Poor</td>
<td>2 (1.1)</td>
<td>5 (2.8)</td>
<td>7 (1.9)</td>
</tr>
<tr>
<td>Current activity level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very active</td>
<td>45 (25.1)</td>
<td>41 (22.7)</td>
<td>86 (25.9)</td>
</tr>
<tr>
<td>Active</td>
<td>101 (56.4)</td>
<td>85 (45.8)</td>
<td>186 (51.1)</td>
</tr>
<tr>
<td>Slightly active</td>
<td>25 (14.6)</td>
<td>51 (26.2)</td>
<td>77 (21.4)</td>
</tr>
<tr>
<td>Sedentary</td>
<td>7 (3.9)</td>
<td>6 (3.3)</td>
<td>13 (3.6)</td>
</tr>
<tr>
<td>Frequency of current manual activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very often</td>
<td>34 (19.0)</td>
<td>23 (12.7)</td>
<td>57 (15.8)</td>
</tr>
<tr>
<td>Often</td>
<td>48 (26.8)</td>
<td>41 (22.7)</td>
<td>89 (24.7)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>29 (16.2)</td>
<td>31 (17.1)</td>
<td>60 (16.7)</td>
</tr>
<tr>
<td>Seldom/never</td>
<td>66 (38.0)</td>
<td>86 (47.5)</td>
<td>154 (42.8)</td>
</tr>
</tbody>
</table>

1M (SD) Range
2Frequency (%)

Table 2

Grip Strength on the Jamar™ Dynamometer and the Martin Vigorimeter (Highest Score on Three Trials) According to Age and Gender

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Jamar™ Dynamometer</th>
<th>Martin Vigorimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Hand (kg)</td>
<td>Left Hand (kg)</td>
</tr>
<tr>
<td></td>
<td>Right Hand (kPa)</td>
<td>Left Hand (kPa)</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-69 years</td>
<td>25.3 (4.8)</td>
<td>23.6 (4.7)</td>
</tr>
<tr>
<td></td>
<td>18-24</td>
<td>12-26</td>
</tr>
<tr>
<td>70-79 years</td>
<td>23.7 (5.1)</td>
<td>22.0 (4.7)</td>
</tr>
<tr>
<td></td>
<td>11-36</td>
<td>10-30</td>
</tr>
<tr>
<td>80 years and older</td>
<td>20.0 (4.3)</td>
<td>18.5 (4.4)</td>
</tr>
<tr>
<td></td>
<td>12-32</td>
<td>10-30</td>
</tr>
<tr>
<td></td>
<td>20-60</td>
<td>24-71</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-69 years</td>
<td>45.6 (8.6)</td>
<td>43.6 (8.7)</td>
</tr>
<tr>
<td></td>
<td>31-70</td>
<td>30-72</td>
</tr>
<tr>
<td>70-79 years</td>
<td>42.4 (8.1)</td>
<td>40.5 (8.5)</td>
</tr>
<tr>
<td></td>
<td>24-69</td>
<td>26-62</td>
</tr>
<tr>
<td>80 years and older</td>
<td>34.5 (7.2)</td>
<td>32.1 (7.0)</td>
</tr>
<tr>
<td></td>
<td>16.5-48</td>
<td>18-47</td>
</tr>
<tr>
<td></td>
<td>36-95</td>
<td>30-105</td>
</tr>
</tbody>
</table>

4M (SD) Range

The same results may be described by regression equations expressing strength as a function of age and their 95% confidence interval (see Table 3). The curvilinear relationship of strength with age required the transformation of the independent variable, namely age.

The predictive equations for strength derived from multiple regressions, where grip strength is the dependent variable and the personal variables of the subjects are the independent variables, are shown in Table 4. For the Jamar™ dynamometer, the variables that best predict grip strength are age and hand circumference, and body weight. For the Martin vigorimeter, age is also the best predictor, but the other predictive variables differ according to gender and side. Residual analysis suggested that the assumptions underlying the regression analysis were satisfied. The standardized residuals appear normally distributed. Moreover, two-dimensional displays of residuals against predicted values and dependent variables did not suggest heterogeneity of variance or lack of linearity.

**Discussion**

The goal of this study was to develop grip strength norms applicable to persons aged 60 years and older. The sample used for this study was randomly recruited and the high participation rate suggests good representation of the population from which it was drawn. Moreover, statistical analyses revealed no difference between those who refused and those who agreed to participate in terms of specific variables, thus minimizing the possibility of a refusal bias.

The highest score on three trials was retained as the grip strength. Even though the reliability is slightly lower than that of the mean of the three measures (Mathiowetz et al., 1984), the highest score appears more valid because it corresponds to the real potential maximum

subjects, the majority of whom are right-handed, were stronger than the left hands (p < 0.0001 for the dynamometer and p = 0.0004 for the vigorimeter). On the Jamar™ dynamometer, these differences are 7.1% for the women and 3.5% for the men, with 5.1% and 2.1%, respectively, on the Martin vigorimeter.

The same results may be described by regression equations expressing strength as a function of age and their 95% confidence interval (see Table 3). The curvilinear relationship of strength with age required the trans-
Table 3  
Age Predicted Maximum Grip Strength and 95% Confidence Interval for Men and Women Aged 60 Years and Older with the Jamar™ Dynamometer and the Martin Vigorimeter

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Predictive Equations</th>
<th>Variability of the Estimated Score</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jamar™ Dynamometer (kg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>35.9 - 0.0020 (age²)</td>
<td>9.2</td>
<td>0.21</td>
</tr>
<tr>
<td>Left hand</td>
<td>35.2 - 0.0020 (age²)</td>
<td>8.5</td>
<td>0.22</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>65.7 - 0.00453 (age²)</td>
<td>15.7</td>
<td>0.20</td>
</tr>
<tr>
<td>Left hand</td>
<td>64.9 - 0.00475 (age²)</td>
<td>15.2</td>
<td>0.24</td>
</tr>
</tbody>
</table>

| **Martin Vigorimeter (kPa)** | | | |
| Women               |                                                             |                                    |     |
| Right hand          | 70.4 - 0.0057 (age²)                                        | 20.6                               | 0.15|
| Left hand           | 67.8 - 0.00503 (age²)                                       | 20.9                               | 0.14|
| Men                 |                                                             |                                    |     |
| Right hand          | 134.6 - 0.0010 (age²)                                       | 30.8                               | 0.36|
| Left hand           | 129.7 - 0.0035 (age²)                                       | 30.1                               | 0.34|

Note. Example: The expected score for maximum right grip strength on the Jamar dynamometer for a 78-year-old man is: 65.7 - 0.00453 (78)² = 38.1 kg.

The expected score for maximum right grip strength on the Martin Vigorimeter depended partially on instructions available with the apparatus and on trials in pretests. The movements of elderly persons are less frequent and the grip strength of older subjects in the present study has, depending on the hand and the instrument, between 54% and 68% of the grip strength of men, which is close to the 60% to 67% found by Aniansson et al. (1980) and the 53% and 57% obtained by Bassey and Harries (1993). Regarding the men, those aged 20 years and older showed significantly less strength than those aged 70 to 79 years (loss in the order of 20% compared with a 15% loss for women in the same age groups). This of type II fibers is controlled for by factorial analysis, age still remains strongly correlated with the decline in strength (Larsson et al., 1979), suggesting that factors other than atrophy of the fast twitch fibers are responsible for this loss of strength with age. Therefore, it should be considered that the decline in muscle strength with age may not be solely due to primary aging of the skeletal muscle but also to secondary changes brought out in the muscle by the aging of other body systems, such as the nervous, vascular, and endocrinal systems (Aniansson et al., 1980) and to a reduction in physical activity (see Grimby, 1986).

Also expected was the finding that men are consistently stronger than women (p < 0.0001). The women in this study have, depending on the hand and the instrument, between 54% and 68% of the grip strength of men, which is close to the 60% to 67% found by Aniansson et al. (1980) and the 53% and 57% obtained by Bassey and Harries (1993). Regarding the men, those aged 20 years and older showed significantly less strength than those aged 70 to 79 years (loss in the order of 20% compared with a 15% loss for women in the same age groups).

Table 4  
Predictive Equations of Maximum Grip Strength Measured With the Jamar™ Dynamometer and the Martin Vigorimeter

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Predictive Equations</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jamar™ Dynamometer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>1.25 (hand circumference; cm) + 0.94 (hand size; cm) - 0.0018 (age²) (\sim 8.21)</td>
<td>0.54</td>
</tr>
<tr>
<td>Left hand</td>
<td>1.46 (hand circumference; cm) + 0.12 (body height; cm) - 0.0018 (age²) (\sim 15.64)</td>
<td>0.38</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>1.52 (hand circumference; cm) + 0.40 (body height; cm) - 0.0055 (age²) (\sim 41.69)</td>
<td>0.45</td>
</tr>
<tr>
<td>Left hand</td>
<td>1.55 (hand circumference; cm) + 0.32 (body height; cm) - 0.0057 (age²) (\sim 30.42)</td>
<td>0.46</td>
</tr>
</tbody>
</table>

| **Martin Vigorimeter** | | |
| Women               |                                                             |              |
| Right hand          | 1.85 (hand circumference; cm) + 0.34 (body height; cm) - 0.0054 (age²) \(\sim 19.96\) | 0.25         |
| Left hand           | 2.24 (hand circumference; cm) + 2.39 (hand size; cm) - 0.0052 (age²) \(\sim 15.30\) | 0.24         |
| Men                 |                                                             |              |
| Right hand          | 0.90 (body height; cm) - 0.0088 (age²) \(\sim 24.56\) | 0.43         |
| Left hand           | 0.58 (body height; cm) + 0.21 (body weight; kg) - 0.0079 (age²) + 6.97 | 0.40         |

Note. The expected score for maximum right grip strength on the Jamar dynamometer for a 78-year-old man with a height of 174 cm and a hand circumference of 24 cm is: 1.52 (24) + 0.40 (174) - 0.0035 (78)² - 41.69 = 35.1 kg.
accentuation in the loss of strength with age among the men agrees with the results of Lundgren-Lindquist and Sperling's study (1983). They attributed this difference between gender to the lower strength among women right from the age of adulthood. These results could also be attributed to the life-style of the very elderly subjects or to a differential aging process depending on gender. In view of the existence of a positive, significant relationship between strength and weight and height and the superiority of men on these variables, Balogun et al. (1991) attributed the difference in strength between the genders to their physical characteristics rather than to biological differences. However, even when the body weight and height of the subjects in the present study are controlled for, the grip strength of the women remains less than that of the men. In a study of the strength of different muscle groups in the upper and lower limbs of a population aged between 62 and 102 years, Rice et al. (1989) also concluded that when body weight is controlled for, grip strength on the dynamometer is significantly different between the genders, but the strength of other muscle groups is not.

Comparison of the Jamar™ dynamometer norms in the present study with those of Mathiowetz et al. (1985) confirms the problem raised by the incorrect calibration of their measuring instrument. In fact, Mathiowetz' scores are lower than those in this study, even when they are compared with the mean values of the three measures of our subjects (not given here). These results reinforce the importance of regularly checking the calibration of the dynamometer and correcting it if needed.

The mean of the right-hand strength of this mainly right-handed sample was stronger than that of the left. This difference approaches that obtained by other researchers (Swanson, Matev, & de Groot, 1974; Toews, 1964) but is far from the 13% found by Lundle et al. (1972) and the 10.75% estimated by Peterson et al. (1989).

Because strength is related to age in a curvilinear rather than a linear fashion, it is important to consider it in the estimation of grip strength; hence, age is squared in the predictive equations. The strength equations in relation to age are more precise than the use of the mean and standard deviation because of the 10-year categories. Because grip strength is not related exclusively to age and that other variables, particularly the anthropometric data, are very important, multivariate analyses were done. The predictive equations deduced from these analyses are made up of the best indicators, among the variables measured, of the grip strength of a person. Thus, age,2 hand circumference, and body height are the variables that best explain the grip strength scores, especially on the Jamar™ dynamometer. Because of the stronger relationship between strength and age,2 the male models predict strength better than the female ones. The models explain between 23% and 46% of the variation in the data, depending on gender and the instrument. Therefore, other variables, ones not measured in the present study, may explain a part of the grip strength of an elderly person. However, while being simple to calculate, these equations produce better estimates of strength than the exclusive use of the scores obtained as a function of age and gender. They should therefore be used clinically.

Study Limitations

This study presents four limitations. First, because the majority of the sample was right-handed, these norms should be used with caution for left-handed persons. Second, the cross-sectional design of the study can introduce a cohort bias because persons born at the beginning of the century have not experienced the same events as younger ones or have experienced the same events under different conditions, which may influence their strength. However, this design does not affect the quality of the normative data. Third, calibration of the Martin vigorimeter was not checked before and during the study. A study by Solgaard, Kristiansen, and Jensen (1984) indicated that the Martin vigorimeter is a precise instrument when tested with a machine to evaluate the linearity of the readings. However, as with the Jamar™ dynamometer, repeated use of the Martin vigorimeter may reduce the precision of its calibration. Finally, although the subjects are representative of elderly persons in the city where they were recruited, they may not be representative of elderly persons as a whole. Even though all the subjects lived in an urban environment, many of them used to live in a rural environment and only moved to the city upon retirement for practical reasons.

Conclusion

Grip strength is a clinical measure that is frequently used to estimate sensorimotor deficits and monitor how they evolve over time. It is an important prerequisite for good hand function. As specialists of hand function evaluation and treatment, occupational therapists must evaluate grip strength correctly and use valid grip strength norms for comparing patients to the normal population. In this study, it was shown that the grip strength of persons aged 60 years and older varies negatively and curvilinearly with age and that the loss seems more marked among the older subjects. The random recruiting of the subjects, the high participation rate, the comparability of those who refused and the subjects who agreed to participate in the study, and the large number of very old subjects give the study the high external validity that is essential to any norm study. This study demonstrated the importance of taking into account hand circumference and body height, in addition to age and gender, when comparing grip strength to that of a population without disability. The predictive equations deduced from the subjects' scores give a more precise estimation of the expected grip strength of elderly patients than would be obtained with only age and gender. ▲
Acknowledgments

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