Differences in Parameters of the Explosive Grip Force Test Between Young and Older Women

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Background. Decreases of strength and speed of muscle contraction are considered major causes of functional impairments in older people. However, the age-related changes in grip force–generating capacity are not clear. The purpose of this study was to measure the parameters of the explosive grip force test and to compare the differences between young and older women.

Methods. Thirty healthy young women (mean age: 22.3 years) and 27 healthy older women (mean age: 78.5 years) participated in this study. All participants performed the maximal explosive grip test three times. Data were recorded as a force–time curve, and the maximal rate of grip force development (max RGFD) and RGFD at intervals of 10 ms up to 250 ms from the onset of contraction were calculated.

Results. The majority of RGFDs of young women were higher than those of the older ones. The maximal grip strength, max RGFD, and max RGFD normalized by the maximal grip strength of older women were 28.3%, 52.4%, and 25.2% less than those of young women, respectively. RGFDs of the older women were not influenced by the maximal grip strength, whereas in young women, those in the late phase of explosive grip force generation showed a moderate correlation with the maximal grip strength.

Conclusions. The present results showed a decrease of the output parameters of the explosive grip force test in older women. Evaluation of explosive grip force generation using RGFD may be used as an assessment tool, providing more detailed information on the grip function.

Key Words: Grip strength—RFD—Aging.

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REDUCTIONS in muscle strength and the speed of muscle contraction are two major causes of functional impairments in the elderly participants (1). Upper limb function plays an important role for normal activities of daily living (ADLs). Incel and colleagues investigated the relationship between grip/pinch strength and the ability of activity using the hands in a questionnaire survey of older people. They found that grip/pinch strength values correlated with the scales of activities using the hands and that reduced muscle function in the hands affects the quality and independence of life in the elderly participants (2).

Age-related reduction in grip strength has been reported in previous studies. Grip strength peaks at the age of 25–39 years and gradually declines thereafter (3–5), though the age-related decline of grip strength production is not well understood. In previous studies of the age-related decline of lower limb muscle force production, Hakkinen and colleagues (6,7) measured the force–time curve during maximal isometric contraction of the quadriceps in 30-, 50- and 70-year-old men and women and reported age-related reductions of the maximal rise rates of force development.

In the assessment of muscle force generation, the parameter most often used is the rate of force development (RFD) (8). The RFD is defined as the slope of the force–time curve (Δforce/Δtime) obtained during isometric muscle contraction (9,10). This parameter has important functional significance in that fast and strong muscle contractions are required in sports (10) and a high contractile RFD exerted during the initial phase of muscular contraction may be of vital importance for successful performance (9).

The handgrip function plays a role in holding and handling objects. In addition, to help the functions of the lower limbs or trunk (eg, grabbing a rail to stand up from a chair or to go up stairs) is also an important role of the hands. The former is a static grip pattern to continue to grip, whereas the latter is a dynamic grip pattern to exert force explosively. A decline of the grip function may be associated with deterioration of ADL or acceleration of instrumental activity of daily living (IADL) impairments. In previous reports, investigations about upper limb functions, especially the grip functions, have focused on the static force. No investigation of grip function from the viewpoint of force generation speed has been reported.
The purpose of this study was to measure the parameters of the explosive grip force test and to compare age-related differences between young and older women. We hypothesized that the RFD in older women would be significantly smaller than that in young women. A deeper understanding of the impact of aging on the grip function will help to understand ADL impairments of older people and the consideration of effective exercises to prevent impairments.

METHODS

Participants
Thirty healthy young women (mean age: 22.3 years, range: 20–27 years) and 27 healthy older women (mean age: 78.5 years, range: 70–92 years) participated in this study. All participants were right handed. Exclusion criteria were neurological disorders with upper limb impairments, upper limb injuries within 6 months prior to our measurements, painful hands including arthritic problems of hands, cardiovascular, or respiratory system disorders, decreased sensation in the hands (not being able to perceive Semmes–Weinstein monofilament #4.08), and a decrease in cognitive function. To avoid bias due to differences in physical activity levels, participants who performed athletic sports or exercises were excluded. Most young participants were college students or staff in the hospital, and most older participants were participants in volunteer activity in the hospital or local health programs.

Before the measurement, written informed consent to participate in the study was obtained from all participants.

Materials
For grip strength measurement, a digital hand dynamometer with a load cell was used (EG-210, Smedley type; Sakai Co. Ltd., Chiyoda-ku, Tokyo). This dynamometer has the capacity to measure from 0 to 60 kgf. The handle setting can be either fixed or movable. In the present study, grip force was measured using the fixed type. The explosive grip test was started at a visible light signal, which was placed on a table 0.5 m from the seat. The light signal and the analog signal from the hand dynamometer were sampled simultaneously at 200 Hz by an analog-to-digital converter (PCD-300A, Kyowa Co. Ltd., Chofu, Tokyo), and data were stored in a personal computer. The accuracy of the PCD-300A is 0.5% × 10⁻⁶. In the present study, because the range was set to 5000 με, the accuracy of the PCD-300A was 0.375 kgf (resolution was 0.103 kgf). The load characteristics of the measuring system were calibrated by using precise force standardized weights of 15, 20, 25, and 30 kg, and our force measurement system was proved to have accuracy of ±3%.

Procedures
The following information was obtained from interviews with all participants: age, body height, and body weight.

The length of the hand from the wrist crease to the tip of the middle finger was measured with a caliper by one examiner.

All participants performed the explosive grip test seated in front of the light signal on the desk with the shoulder adducted and neutrally rotated, elbow fully extended, and the forearm and wrist in the neutral position. The adjustable handle of the dynamometer was set at half the length from the tip of the index finger to the first interdigital space of each participant.

The explosive grip test was performed by one examiner. The examiner instructed each participant as follows: “Squeeze the dynamometer as hard and as fast as possible immediately after the light signal is turned on and keep gripping it with maximal effort for 6 seconds.” Six seconds later, the examiner said, “Stop.” To avoid the influence of motivation, the examiner did not encourage any participant during the explosive grip tests. Participants practiced the explosive grip test at 80% submaximal strength twice, 10 minutes before the test. A zero adjustment was performed with the dynamometer held by the participant before measurement. The examiner confirmed that the force–time curve was displayed at the zero level and then pushed the button of the light signal. All participants performed three explosive grip tests with 3-minute intervals between the tests.

Data Analysis
All data were recorded and analyzed using the software program PCD-30A (Kyowa Co. Ltd., Chofu, Tokyo).

To exclude the effect of individual reaction time, that is, the time from the light signal to the rising of the force–time curve, we defined the onset of the force–time curve as the point when the rise of grip force was recorded from the zero baseline value. The maximal grip force in kilogram force and the rate of grip force development in kilogram force per second were calculated using the obtained force–time curves.

Two rates of grip force development were calculated in this study (Figure 1). First, the maximal rate of grip force development (max RGFD), defined as the maximal value of the slope of the force–time curve in each 10-ms interval (ie, Δforce/10 ms), was calculated. Second, the rate of grip force development (RGFD), defined as the slope of the force–time curve (ie, Δforce/Δtime) at intervals of 10 ms up to 250 ms, with each measurement using point 0 as the baseline, was calculated (9). Additionally, max RGFD normalized by the maximal grip force was calculated (ie, max RGFD/maximal grip force).

Statistics
Data from 30 young women and 27 older women were analyzed statistically. The mean value of three measurements with the dynamometer was used for statistical analysis. The data are given as group mean values ± SD.
Test–retest reliability of all parameters was evaluated for the initial 11 participants in the group of young women. Intraclass correlation coefficients were .70–.95, confirming that all parameters showed high reliability. All differences between the young and older women were evaluated with Student’s t test for independent samples (.05 level of significance). Additionally, Pearson’s product moment correlation coefficient (r) was calculated to determine the intragroup association between the maximal voluntary grip force and max RGFD or each RGFD. All analyses were performed using SPSS for Windows 17.0 (SPSS Inc., Chicago, IL).

RESULTS
General characteristics of the participants are presented in Table 1. The maximal voluntary grip strengths in the old and young women were 20.3 ± 4.5 and 28.3 ± 3.6 kgf, respectively, and older women showed significantly lower grip strength than young women (t = 7.458, df = 55, p < .0005). The maximal grip strength of older women was 28.3% less than that of young women.

Table 2 shows max RGFD and max RGFD normalized by the maximal grip strength. Max RGFD in older women was significantly smaller than in young women (t = 8.301, df = 55, p < .0005). Max RGFD normalized by the maximal grip strength of older women was significantly smaller than that of young women (t = 4.106, df = 55, p < .0005). Max RGFD of the older group was 52.4% less than that of the young group, and normalized max RGFD of the older group was 25.2% less than that of the young group. Figure 2 shows RGFDs from the onset of contraction to 250 ms. All RGFDs from the onset of contraction for older women were smaller than for young women, except for that at 20 ms (p < .05–.0005).

Figure 3 shows the intragroup correlation coefficients between maximal voluntary grip strength and each RGFD. In the older group, there was a nonsignificant correlation between all RGFDs and maximal grip strength. In the young group, significant correlations between these variables were obtained when RGFD was determined for time intervals later than 90 ms from the onset of contraction.

DISCUSSION
Our results showed that the maximal grip strength and max RGFD were significantly smaller in older women than in young ones. Max RGFD was 52.4% less in the old. The decrease of max RGFD was twice as large as that of the maximal grip strength (28.3%), and max RGFD normalized by the maximum grip strength of the old was 25.2% less than that of the young. In previous studies, it has been reported that age-related differences in slow-speed isokinetic peak torque values are similar to those of isometric values, but greater age-related differences are observed at faster speeds (11). In the present study, age-related decreases of grip force–

Table 1. General Characteristics of Subjects (mean ± SD)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Young Women (n = 30)</th>
<th>Older Women (n = 27)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.3 (range: 20–27)</td>
<td>79.0 (range: 70–92)</td>
<td></td>
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<tr>
<td>Height (cm)</td>
<td>158.3 ± 4.2</td>
<td>149.1 ± 4.8</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>52.7 ± 6.6</td>
<td>51.5 ± 8.0</td>
<td>.56</td>
</tr>
<tr>
<td>Hand size (cm)</td>
<td>17.2 ± 0.9</td>
<td>16.9 ± 1.0</td>
<td>.26</td>
</tr>
<tr>
<td>Grip strength (kgf)</td>
<td>28.32 ± 3.55</td>
<td>20.30 ± 4.54</td>
<td>&lt;.0005</td>
</tr>
</tbody>
</table>

Table 2. Max RGFD and Max RGFD Normalized by Grip Strength

<table>
<thead>
<tr>
<th></th>
<th>Young Women (n = 30)</th>
<th>Older Women (n = 27)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max RGFD (kgf/s)</td>
<td>186.42 ± 51.21</td>
<td>88.68 ± 35.24</td>
<td>&lt;.0005</td>
</tr>
<tr>
<td>Normalized max RGFD</td>
<td>6.34 ± 1.23</td>
<td>4.74 ± 1.68</td>
<td>&lt;.0005</td>
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generating capacity were found for both max RGFD and normalized max RGFD, confirming the decline of the grip function by two different gripping parameters.

In the investigation of the relationship between RGFD from the onset of contraction to 250 ms and maximal grip strength, our results showed that RGFD in young women were greatly influenced by maximal grip strength. However, in older women, they were hardly influenced by maximal grip strength even though max RGFD and maximal grip strength were significantly smaller than for the young women (Figure 3). Andersen and colleagues (9) reported that RFD later than 90 ms from the onset of contraction was strongly related to maximal voluntary contraction. Our results agreed with Andersen and colleagues in the case of young women, but in the case of older women, the data were not consistent with their study; rather, RFD in grip was independent of maximal grip strength.

The variety of the grip function in older people may not be explained by maximal grip strength alone. Clark and colleagues (12) investigated the rate of the electromyographic rise of the quadriceps and power of the knee extension in middle-aged and older adults. They reported that the rate of the electromyographic rise demonstrated nonsignificant differences between the two groups; however, the rate of the electromyographic rise was associated with the score of the Short Physical Performance Battery and the power of knee extension. A significant decrease was observed in the power of the knee extension during a relative force level of 70% in older adults. They investigated the stage of neuromuscular activation, which was earlier than the stage we studied. Based on their results, it is possible that the decrease of RGFD in the explosive grip force test in older women comes from altered ability of muscle contraction.

Sayers and colleagues (13) reported that muscle contraction velocity of lower limbs better explained the variability in functional tasks than strength in older women. The decline in manual function has been attributed to decreases in muscle mass, strength and coordination, finger dexterity, and sensation as well as alterations of the central nervous system (2). Moreover, the physical activity level is related to physical function and mobility in older persons (14).

Nalebuff has suggested that a grip strength of 20 lb is needed to perform most daily activities (15). Rahman and colleagues (16) reported that strong relationships did not exist between grip strength and the amount of force required to use daily tools, for example, to open containers. Therefore, it is considered that high grip strength is not necessary to perform general ADLs. However, Jette and colleagues (17) reported that the progression of hand impairments with age was related to increasing basic ADL disability, and Taekema and colleagues (18) reported that lower grip strength was significantly correlated with ADL and IADL disabilities in the elderly participants. These findings suggested that the decrease of upper limb function makes it difficult for older persons to live independently. Hakkinen and colleagues (6) suggested that explosive-type strength training could contribute to attempts made to maintain the daily functional capacity of older people at as high a level as possible for as long as possible.

Because many factors are related to ADL/IADL disabilities in the old (19) and no other evaluation except for grip strength was performed in the present study, we cannot draw further conclusions. More research about the relationship between the grip function and ADL/IADL disabilities is necessary. It might also help to consider better methods to maintain the independent ADL and IADL of older persons.

Our results suggest the possibility that the evaluation of explosive grip force generation using RGFD can be used as an assessment tool providing more detailed information on the grip function, and we plan to conduct additional research about the relationship between RGFD and hand performance.

### Conclusions

We compared the RGFD in the explosive grip force test between young and older women, and our results showed a significant decrease of RGFD as well as of maximal grip strength in the older women. Additionally, the age-related decrease of RGFD was greater than that of the maximal grip strength. These results indicate that explosive grip force–generating capacity is influenced more by aging than the maximal grip strength. The intragroup correlation coefficients between the maximal grip strength.
and RGFDs indicated that all RGFDs of older women were independent of maximal grip strength. In young women, RGFDs in the late phase of the explosive grip force test showed a moderate correlation with the maximal grip strength. Evaluation of explosive grip force generation using RGFD may be used to assess upper limb function, providing detailed information, and future efforts should investigate the relationship between RGFD and hand performance to improve this method of assessment.

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