A Comparative Study of Adjustability of Grasping Force between Young People and Elderly Individuals

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Abstract: Purpose: This study aimed to compare adjustability of grasping force (AGF) between people belonging to young and elderly age-groups.

Methods: Twenty young people and 20 elderly people, with no previous pathology involving the hands and fingers, were included in the study, and an AGF assessment was performed for all the subjects using an iWakka. Subjects adjusted the grasping force according to the target value displayed on the monitor by opening or closing the iWakka.

Results: The assessment of AGF was performed separately from that of the gripping force, and the latter was found to be comparable between the two groups. The mean AGF was found to be 8.9 ± 4.0 g and 7.6 ± 2.8 g for the dominant and the non-dominant hand, respectively, in the elderly group, as compared to the mean AGF for the dominant and the non-dominant hand of 4.4 ± 1.2 g and 4.4 ± 0.6 g, respectively estimated in the young age-group. A t-test conducted after controlling the disparate factors (sex, handedness, gripping force) between the subjects of the two groups, showed that there was a significant difference in AGF between the young and the elderly groups for both the dominant (p = 0.03) and the non-dominant hand (p = 0.02), indicating that the AGF of the elderly people was significantly lower than that of the young study-subjects.

Conclusions: Our findings suggest that AGF decreases with aging and that it is necessary to assess AGF separately from the gripping force, to make a precise comparison.

Keywords: adjustability of grasping force, iWakka, elderly people, gripping force

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1. Introduction

The functions of hands and fingers involve making grabbing, gripping, pinching, hooking, scooping, and pressing movements, which play an important role in performing daily activities [1]. Therefore, in many instances, rehabilitation centers have developed interventional programs for training patients to resume activities of daily living (ADL), based on the results of functional assessment of their hand and finger movements. Currently, an assessment of gripping force, the Purdue Pegboard Test [2], the O’Connor Finger Dexterity Test [3, 4], the Jebsen-Taylor Hand Function Test [5], and an examination of the physical capacity of hand-related skills [6], are utilized widely for assessing the hand and finger functions. Since these tests depend on an evaluation of both the time taken to complete a task and the degree to which the task is achieved, they can assess the maximum functional output while attempting to complete a task. However, while performing ADL, though there are tasks for which maximum force output is indicated, there are also those which require the capability of adjusting the exertional force, both chronologically and spatially, in a continuous manner and at a level below the maximum, without dropping a grasped object, further defined by its
shape, weight, and type of material. This capability is referred to as the adjustability of grasping force (AGF).

A specialized device, called an iWakka, has been developed for the purpose of measuring AGF. Assessments performed using this device allow insights into the patient’s actual AGF capability, which other existing modalities cannot evaluate [7–9]. Kaneno et al. [10] verified the reliability of an AGF-assessment method in young adults using an iWakka. Kaneno et al. [11] also verified the reliability of using this device for AGF evaluation in elderly individuals. These studies reported that AGF assessments performed using an iWakka provide reliable data on the AGF of people belonging to both the young and elderly age-groups.

Studies have reported that compared to young subjects, the elderly ones tend to have reduced hand and finger functions, indicated by evaluating various parameters including gripping force and fine motor skills [12, 13]. Conversely, with respect to certain mental skills such as comprehending a story from the context and for recall related to prospective memories [14, 15], elderly people demonstrate a capability equivalent to that observed in young subjects. These insights about the types of abilities that elderly individuals need assistance can help provide targeted preventive assistance. However, there have been no reports on a comparison of AGF between young and elderly individuals, and no data are available on whether elderly individuals have a reduced AGF as compared to the young age-group. Therefore, this study aims to compare AGF between people belonging to young and elderly age-groups.

2. Methods

2.1 Subjects

The eligibility criteria for the young subjects included in the study were 20 ≤ age < 30 years and being affiliated to the Faculty of Health Sciences, Mejiro University, in Japan. Exclusion criteria were having an experience of carrying out tasks similar to those required to be performed for this study, or having a current or past (history of) orthopedic or neurological disease of the hands and fingers that impacted ADL. The eligibility criteria for elderly individuals subjects were age ≥ 65 years, those living in their own homes (main place of residence), and those able to ambulate without a walking-aid and able to travel to the study venue by themselves. The exclusion criteria for the latter group were having an experience of carrying out tasks similar to those required to be performed for this study, or scoring ≤ 23 on the Mini-Mental State Examination (MMSE).

In order to estimate the sample size required for this study, we conducted a pilot survey of a small group (n = 10) consisting of 5 young people and elderly people, respectively. The results showed that the effect size of the AGF value (the main outcome of this study) for this small-sized sample was 1.17. We estimated the size of the study-sample required for the study, from the effect size of AGF value on the test group, using software G*Power [16] at a setting of α = 0.05 and β = 0.20, which showed that an evaluation of at least 10 subjects in each group would be necessary to obtain statistically viable results. In order to adjust for confounding factors arising from matching of subjects, we recruited 20 subjects each for the young and elderly study groups.

All subjects received written and verbal explanation of the objectives and the study protocol in advance. All subjects included in the study provided written, informed consent for participation. The study protocol was approved by the research ethics review board of the Mejiro University (Approval number: 17-007).

2.2 Outcome measures

2.2.1 AGF assessment

In this study, we used the device iWakka (Aimu Co., Ltd.) for assessing the AGF of the study subjects. The device has a cylindrical shape with an 80-mm height and a 65-mm diameter. It consists of attached hinges for fixation to one of the edges of the cut-vinyl chloride pipe, and plate springs are placed within the pipe in such a manner that they cross each other [7, 8] (Fig. 1). Opening or closing the iWakka causes the plate springs to distort. We measured the level of distortion with a gauge and used a computerized analysis to create a real-time graph indicating the variability of the grasping force (in grams) over time (in seconds). Subjects were instructed to adjust the grasping force according to the target value displayed on the monitor. The maximum target value used was 400 g. The target value was changed in a stepwise manner at certain time intervals. The displayed values moved from right to left on the graph, with the passage of time. Quantitative evaluation is possible by calculating the absolute value of error, between the target value and the measured value of grasping force as AGF. A smaller the absolute values were indicative of a better AGF (Fig. 1).

With reference to the methods described in older studies [11, 17], the test environment was arranged as follows (Fig. 1). The assessment was conducted in a quiet environment. An adjustable table was utilized with its height adapted to the test subject’s preference, based on the distance from their seat or chair to the table, to increase the ease of using the device. In order to
maintain a uniform seating position and posture for all study subjects, no backrest was provided. The subjects were seated with their legs shoulder-width apart and their knee joint was kept in a 90 degrees flexed position. The distance from the table to the body was maintained at 10-cm, and the monitor was placed at a distance of 50-cm from the edge of the table. Subjects were instructed to maintain the position of the test-hand in the “Functional position”, i.e. in dorsiflexion at 30° with the metacarpophalangeal joint of the digitus minimus attached to an acrylic plate. In order to eliminate the impact of the upper arms and maintain an equal shoulder height during measurement, the subjects were seated with both elbows on the table with both their forearms positioned at a point in-between pronation and supination, while the iWakka was placed on the acrylic plate, so that the device would not be tilted.

2.2.2 Assessment of gripping force

An analog tester (Takei Scientific Instruments Co., Ltd.) was utilized to measure the gripping force for all subjects. With reference to the positioning method described by Edo et al. [18], in this study, the gripping-force measurements were performed with subjects seated upright with their upper limbs placed down along the body. The gripping width was set in such a manner that the proximal interphalangeal joint of the index finger was bent at 90°. Since it has been reported that measuring the one-time gripping-force provides reliable data [19], we also carried out only one-time measurement of the gripping force for each study-subject.

2.3 Measurement procedure

Firstly, basic information such as age and gender was collected in an interview. Following this, a laterality index was estimated using the Edinburgh Handedness Inventory [20] to determine the dominant hand in each subject. As per the criteria described by Sakano [21], those with a laterality index value from 80−100 were determined to be right hand-dominant, and those with scores from −20 to −100 were considered to have a dominant left hand. Thereafter, prior to the assessment, a short practice session was conducted for each subject to familiarize them with the details of the tasks to be performed using the iWakka. Different target values were used from those in the assessment for this practice. A five-minute break was given after completion of the practice tasks, and the assessment were carried out in
the same environment as that used for practice. Subjects performed assessment tasks twice each with the dominant and the non-dominant hand, and the mean value of the two attempts was used as the measurement value. In order to eliminate the effect of order of testing, counter-balancing was used by dividing the subjects into those who started the assessment with their dominant hands and with their non-dominant hands, respectively.

2.4 Data analysis

Subjects were categorized into a young group and an elderly group. The Chi-square test was used to analyze the distribution of baseline characteristics including sex and handedness, between the two groups. Furthermore, the groups were compared using t-tests for independent samples, in order to evaluate deviations in the values of both gripping force and AGF.

We performed adjustment to control variations in factors including sex, handedness and gripping force so that the difference between the two groups would only be limited with respect to age to the maximum possible extent. Subject-matching was conducted between both groups for the comparative analysis of AGF. While performing the analysis, factors, including both sex and the dominant hand of the subjects, were completely matched (e.g., right-handed young men and right-handed elderly men). In addition, the permissible ranges of gripping force were set at ± 5 kg and ± 3 kg for males and females, respectively, and the pair whose values of gripping force were as similar as possible were matched. As per data on variations in gripping force with age, issued by the Japanese Government Ministry of Education, Culture, Sports, Science and Technology, the standard deviations in both males and females aged 70−74 years were smaller than in those aged 20−24 years. In our study, the standard deviations among males and females aged from 70−74 years were referred to for setting the standard deviation values [12]. After matching, a t-test for analysis of independent samples was repeated.

The software IBM SPSS Statistics 25 was used for statistical analysis, and the level of significance was set at 5%.

3. Results

The mean age of the group of 20 young subjects was 21.0 ± 0.7 years (95% confidence interval [CI]: 20.7, 21.3), and it included 4 males and 16 females. Nineteen subjects were right-dominant, while 1 was left-dominant (Table 1). The mean gripping force for the dominant and the non-dominant hand was found to be 26.9 ± 6.4 kg (95% CI: 24.0, 29.9) and 24.9 ± 7.1 kg (95% CI: 21.6, 28.2), respectively. The mean AGF for the dominant and the non-dominant hand was calculated as 4.4 ± 1.2 g (95% CI: 3.8, 5.0) and 4.4 ± 0.6 g (95% CI: 4.1, 4.7), respectively, in the young age-group.

The mean age of the group of 20 elderly subjects was 71.1 ± 4.1 years (95% CI: 69.1, 73.0), and it included 15 males and 5 females (Table 1). The mean MMSE score of the group was 28.8 ± 2.0 points (95% CI: 28.1, 29.4), and all 20 subjects were found to be right-dominant. The mean gripping force was 29.1 ± 7.8 kg (95% CI: 25.4, 32.7) and 28.4 ± 8.2 kg (95% CI: 24.5, 32.2) for the dominant and the non-dominant hand, respectively. The mean AGF was 8.9 ± 4.0 g (95% CI: 7.0, 10.7) and 7.6 ± 2.8 g (95% CI: 6.3, 8.9) for the dominant and the non-dominant hand, respectively, in the elderly group.

An analysis of AGF between the two groups through a t-test indicated that it was significantly lower in the elderly group than in the young group for both the dominant and non-dominant hands (p < 0.01 for both, Cohen’s d = 1.52, Cohen’s d = 1.58, respectively) (Table 1). No significant difference in gripping force was observed between the two groups for both dominant and non-dominant hands (p = 0.35 and p = 0.17, respectively). The number of female subjects was significantly larger in the young group, and that of male subjects was significantly larger in the elderly group (p = 0.03). No significant difference in the number of right and left-dominant was observed between the two groups (p = 0.31).

The two groups were matched for sex, the dominant hand, and the gripping force of the subjects, in order to control these factors (Table 2). Following matching, the number of subjects in in each of the two groups was 6 with a sex-distribution of 2 males and 4 females in each group. A t-test conducted after controlling the disparate factors (sex, handedness, gripping force), showed that there was a significant difference in AGF between the young and the elderly groups for both the dominant (p = 0.03, Cohen’s p = 1.61) and the non-dominant (p = 0.02, Cohen’s p = 2.04) hands, indicating that the AGF of the elderly subjects was significantly lower than that of the young subjects.

4. Discussion

Since there have been no AGF-assessment methods described in existing literature, it was unclear whether elderly individuals had a higher or lower AGF as compared to that of young people. However, this study showed that elderly people have lower AGF than young people, even after performing adjustment for sex, handedness and gripping force of the test-subjects. It has been reported that since innervation ratio increases with
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Table 1. A comparison of adjustability of grasping force between the young and the elderly study-groups.

|                      | Young group | Elderly group | p  | Cohen’s d |
|----------------------|-------------|---------------|----|-----------|
|                      | n = 20      | n = 20        |    |           |
| Age (year)           | 21.0 ± 0.7  | 71.1 ± 4.1    |    |           |
| Gender (no. of people) | Male | 4 | 15 | 0.03    |
|                      | Female  | 16 | 5 |           |
| MMSE (score)         |            | 28.8 ± 2.0    |    |           |
| Dominant hand (no. of people) | Right | 19 | 20 | 0.31    |
|                      | Left      | 1 | 0 |           |
| Gripping force (kg)  | Dominant hand | 26.9 ± 6.4 | 29.1 ± 7.8 | 0.35 | 0.31 |
|                      | Non-dominant hand | 24.9 ± 7.1 | 28.4 ± 8.2 | 0.17 | 0.46 |
| AGF (g)              | Dominant hand | 4.4 ± 1.2 | 8.9 ± 4.0 | < 0.01 | 1.52 |
|                      | Non-dominant hand | 4.4 ± 0.6 | 7.6 ± 2.8 | < 0.01 | 1.58 |

AGF: adjustability of grasping force; MMSE: Mini-Mental State Examination.

Table 2. A comparison of adjustability of grasping force between the young and the elderly groups after performing adjustment for factors including sex, handedness and gripping force of the subjects.

|                      | Young group | Elderly group | p  | Cohen’s d |
|----------------------|-------------|---------------|----|-----------|
|                      | n = 6       | n = 6         |    |           |
| Age (years)          | 21.2 ± 1.0  | 70.5 ± 3.9    |    |           |
| Gender (no. of people) | Male | 2 | 2 | 1.00    |
|                      | Female  | 4 | 4 |           |
| MMSE (score)         |            | 29.0 ± 2.2    |    |           |
| Dominant hand (no. of people) | Right | 6 | 6 | 1.00    |
|                      | Left      | 0 | 0 |           |
| Gripping force (kg)  | Dominant hand | 24.8 ± 7.4 | 24.6 ± 7.7 | 0.97 | 0.03 |
|                      | Non-dominant hand | 22.9 ± 9.5 | 21.9 ± 7.5 | 0.84 | 0.12 |
| AGF (g)              | Dominant hand | 4.9 ± 2.0 | 12.2 ± 6.1 | 0.03 | 1.61 |
|                      | Non-dominant hand | 4.5 ± 0.8 | 9.4 ± 3.3 | 0.02 | 2.04 |

AGF: adjustability of grasping force; MMSE: Mini-Mental State Examination.

age, elderly people tend to find it difficult to perform precise movements that require a subtle adjustment of force [22, 23], and the impairment was considered to be related to a decrease in AGF in this population. Additionally, a report has also suggested that the in elderly individuals, the capability of adjusting force while holding an object reduces, because the sensitivity of sensory receptors including those responsible for tactile sensibility and mechanoreception, declines with age [24]. The Japanese Association of Occupational Therapists [25] has reported that about 30% of elderly people, who have no specific diseases and are living in the community, find it difficult to perform certain everyday tasks, indicating a difficulty in conducting their ADL. The Association develops occupational therapeutic interventions with a focus on ADL, and the effects of such interventions have been published [26]. This study demonstrated that local elderly residents who can apply the same level of gripping force as that exerted by young people demonstrate a lower AGF than young people. Since AGF is the capability of adjusting the force exerted while holding any object (depending on its shape, weight and material), it can be considered that individuals with reduced AGF may face difficulties in performing actions in their everyday lives, such as dropping a grasped object or accidentally crushing an
object in the hand. Therefore, this study suggested that it is necessary to assess the AGF of elderly people separately from gripping force and have an understanding of to what degree their AGF has been reduced from an early stage, in order to alleviate difficulties which local elderly residents face in their everyday lives.

The elderly population is expanding at a global level, and it is particularly expected to rapidly increase in Japan [27]. Consequently, Japan is also expected to start facing difficulties related to the care of this age-group relatively earlier than other countries, and the manner in which, the country would address such issues is currently of interest to the international community. The World Federation of Occupational Therapists [28] has expanded its scope for occupational therapy to be extended not only to those with health problems but also to any individuals, who are occupationally involved, indicating that those who do not have health issues can also benefit from the therapy. Preventive interventions have been provided through occupational therapy, based on knowledge related to the reduced capabilities of elderly people as compared to those of young people [29−31]. This study elucidated that elderly individuals have significantly reduced AGF as compared to young people, suggesting that it is necessary to provide interventions for this reduced capability from a preventive perspective.

This study, after making adjustments for factors including sex, handedness and gripping force of the subjects, was able to determine that the AGF of elderly people was lower than that of young people. However, the number of pairs assumed in advance was not created as a result of matching. Therefore, we calculated the actual power from the effect size of AGF value on the two groups following matching, using software G*Power at a setting of α = 0.05 and sample size of 6. The results indicated that the power of our comparison for both dominant hand and non-dominant hand was sufficient (power = 0.71, power = 0.89, respectively), as the effect size after matching was higher than before matching. In addition, the impact of reduced AGF on ADL has not been elucidated till date, indicating the necessity of further research on this aspect. Moreover, while this study indicated that AGF may reduce with aging, it did not clarify what kind of factors may have been responsible for the reduction. In particular, AGF may be affected by hand size and sensory function. Therefore, in the future, in order to provide effective interventions for reduced AGF, it is necessary to elucidate these factors that influence AGF. Also, further investigations of AGF, not only of elderly individuals able to live in the community, but also of weaker elderly people and those facing difficulties in their everyday lives are required, in order to accumulate knowledge that will be useful in developing effective intervention programs for this vulnerable age-group.

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