*Original Article*

# Development of Gait Ability Assessment for hemiplegics (GAA) and verification of inter-rater reliability and validity

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## ABSTRACT

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**Objective:** To develop the Gait Ability Assessment for hemiplegics (GAA), and to verify its validity and inter-rater reliability.
**Methods:** We developed the GAA, a new method for the assessment of gait ability. Next, we examined the inter-rater reliability of GAA by assessing gait ability of post-stroke patients by two physical therapists. Then, we verified the validity of GAA by comparing with the existing assessments methods comprising Functional Ambulation Categories (FAC), Functional Independence Measure (FIM)-walk, maximum walking speed, motor subscore of the FIM (FIM-M), and total score of affected-side motor function of the Stroke Impairment Assessment Set (SIAS-L/E).
**Results:** Regarding the inter-rater reliability of GAA, $\kappa$ coefficient was 0.76 and weighted $\kappa$ coefficient was 0.96. The correlation coefficients between GAA scores and existing assessment methods were: 0.95 for FAC scores, 0.95 for FIM-walk scores, 0.82 for maximum walking speed, 0.89 for FIM-M, and 0.61 for SIAS-L/E, all of which showed a significant correlation ($p<0.01$).
**Conclusion:** GAA has high inter-rater reliability as well as high validity as a gait ability assessment method, suggesting that it can be applied to research and clinical settings.
**Key words:** stroke, Gait Ability Assessment for hemiplegics (GAA), inter-rater reliability, validity

## Introduction

Gait restoration after stroke is an important goal of post-stroke rehabilitation programs [1, 2]. Therefore, proper assessment of gait ability to guide progress in gait training is essential.

Walking speed [3, 4] and walking distance [2, 5] are used to assess the gait ability of post-stroke patients, but these assessments are mainly for patients with high walking ability who do not require assistance. When assessing gait ability using the same indicator for patients including those with low gait ability, the degree of gait independence has been used [6−8].

Methods for the assessment of gait independence include walking in the Barthel Index (BI) [9], the Functional Ambulation Categories (FAC) [10], and locomotion in the Functional Independence Measure (FIM) [11]. Walking in BI is assessed in three grades of "immobile," "with help," and "independent"; the grading is rough and does not consider the difference in amount of assistance. FAC is assessed on a 6-point scale (scores 0 to 5), and although assisted gait is rated in three grades (scores 0 to 2), low responsiveness in patients with low gait ability has been reported [12], and detailed tracking of the change in amount of assistance is difficult.

In FIM, walk (FIM-walk) is included within the items of locomotion, and is scored on a 7-point scale (scores 1 to 7), which facilitates tracking of the change in degree of independence. Scores 1 to 4 assess the walking effort performed by the patient in 25% increments. Score 5 is supervision level or the ability to walk short distances (15 m) independently; score 6 is modified independence; and score 7 is complete independence. The scoring of FIM-walk includes the factor of walking distance. For a patient who cannot walk 50 m or longer, he/she scores 5 if capable of walking independently for 15 m, and scores 2 or 1 depending on whether he/she performs 25% or more of the walking effort. While these scoring criteria are considered to appropriately reflect activities of daily living, they may deviate from the gait ability observed in gait training and gait assessment settings.

We have developed a new gait ability assessment method called Gait Ability Assessment for hemiplegics (GAA), in order to accurately capture the changes in the degree of gait independence by utilizing the FIM scoring criteria. GAA1 to GAA4 are scored in 25% increments depending on the amount of assistance, and concrete examples of assisted gait are provided. The judgement criterion for GAA5 is supervision only, and GAA5 is divided into GAA5a for close supervision and GAA5b for distant supervision. GAA6 is modified independence, and GAA7 is complete independence. The purpose of this study was to verify the inter-rater reliability and validity of GAA when used to assess post-stroke patients.

## Methods

### 1. Procedures of GAA development

First, two physical therapists engaged in stroke rehabilitation (with 11 and 13 years of clinical experience) and two rehabilitation medical specialists (with 10 and 29 years of clinical experience) assumed scenarios commonly experienced during gait training of post-stroke patients and constructed 20 questions that would clearly illustrate the amount of assistance the patients were receiving (Table 1). Considering that the same assistance would not be given in every gait cycle during assisted gait, expressions of frequency such as "provides assistance one out of three gait cycles" were used as appropriate.

Next, 13 physical therapists with clinical experience of 8 years or longer (10.5±3.0 years) working at a university hospital were recruited, and asked to respond to each of the 20 questions as follows: "Please read each of the statements, and indicate what percentage of the movements is performed by the patient him/herself, on a scale of 0% (patient not performing any movement) to 100% (patient performing all the movements)."

From the responses to the questions, we calculated the mean and standard deviation of the amount of movement performed by the patient for each question.

We selected the questions with mean percentage closest to 12.5% (mean of 0% and 25%), 37.5% (mean of 25% and 50%), 62.5% (mean of 50% and 75%) and 87.5% (mean of 75% and 100%) as concrete examples corresponding to score 1 to score 4, respectively, of GAA.

### 2. Verification of reliability and validity of GAA
### 2.1 Subjects

Seventy-eight post-stroke patients who were hospitalized in the comprehensive inpatient rehabilitation wards of Fujita Health University Nanakuri Memorial Hospital on X month Y day and X month Y+1 day in 2016 were candidates for this study. Among these patients, 17 who had difficulties with gait assessment were excluded. Eventually, 61 patients were studied (Table 2). All subjects received physiotherapy and occupational therapy 7 days per week according to the FIT (Full-time Integrated Treatment) program [13].

### 2.2 Assessment items and assessment schedule

A physical therapist with 14 years of experience (hereinafter referred to as assessor A) and a physical therapist with 13 years of experience (hereinafter, assessor B) assessed gait ability using GAA on the same day. In addition, on the same day of GAA assessment, the physical therapists in charge other than assessors A and B collected data including age, sex, duration from onset to the date of GAA assessment (hereinafter, duration after onset), and duration from date of admission to the date of GAA assessment (hereinafter, hospitalization period), and assessed the total score of hip-flexion test, knee-extension test, and foot-pat test, which are motor functions of the affected-side lower limb of the Stroke Impairment Assessment Set (SIAS) [14] (hereinafter, SIAS-L/E), motor subscore of the FIM (FIM-M), FAC score, FIM-walk score, and maximum walking speed. Gait ability was assessed using the assistive devices and orthoses used in physical therapy setting.

The Fujita Health University Rehabilitation Complex has set up an independent test to evaluate the proficiency level of FIM scoring, and correct answer rates of 80% or higher are required to pass the test. All the physical therapists who performed gait assessment in this study passed this test.

### 2.3 Statistical analyses

Statistical analyses were performed using SPSS Statistics 19 (International Business Machines Corp., Armonk, NY, USA). Inter-rater reliability of GAA was analyzed using Cohen's $\kappa$ coefficient [15] and weighted $\kappa$ coefficient. Criterion-related validity of GAA was analyzed using Spearman's rank correlation coefficient between GAA scores assessed by assessor A and SIAS-L/E scores, FIM-M scores, FAC scores, FIM-walk scores, or maximum walking speed.

**Table 1.** Proposed concrete descriptions of scenarios during gait training of post-stroke hemiplegic patients.

| Question No. | Draft concrete descriptions |
|---|---|
| 1 | Therapist supports and raises the upper body from the back, holds the thigh cuff of the KAFO to swing out the affected limb, and assists the trunk and hip joint even in stance. In addition, another therapist is required to assist with cane positioning. |
| 2 | Cane and AFO are used. Therapist holds the pelvis from both sides, and uses a strong force to assist swing out of the affected limb and assist in shifting of the center of gravity, so that the knee does not buckle during stance. |
| 3 | Therapist holds the thigh cuff of the KAFO to assist swing out of the affected limb. In addition, another therapist is required to assist with cane positioning. |
| 4 | Cane and AFO are used. Therapist assists in shifting the center of gravity 1 out of 3 gait cycles when the affected limb cannot swing out. No assistance is required for stance of the affected limb. |
| 5 | Therapist uses a weak force to prevent pelvis drift in every gait cycle during stance of the affected limb. An AFO is used. No assistance is required for swing out of the affected limb. |
| 6 | Therapist uses a weak force to prevent pelvis drift 1 out of 3 gait cycles during stance of the affected limb. AFO is used. No assistance is required for swing out of the affected limb. |
| 7 | Therapist prevents pelvis drift in every gait cycle during stance of the affected limb, and holds the thigh cuff of the KAFO to assist swing out of the affected limb. |
| 8 | Cane and AFO are used. Therapist touches the patient's body lightly to prevent falls. |
| 9 | Therapist uses a weak force to prompt shifting of the center of gravity to the unaffected limb in every gait cycle to assist swing out of the affected limb. Weight support is not required. AFO is used. |
| 10 | Therapist uses a strong force to prevent pelvis drift in every gait cycle during stance of the affected limb. AFO is used. No assistance is required for swing out of the affected limb. |
| 11 | Therapist raises the upper body from the back, holds the thigh cuff of the KAFO to swing out the affected limb, and assists the trunk and hip joint even in stance. The patient can operate a cane. |
| 12 | Cane and KAFO are used. Therapist holds the pelvis from both sides, and uses a weak force to assist swing out of the affected limb and left-right shifting of the center of gravity in stance. |
| 13 | Therapist raises the upper body from the back, holds the thigh cuff of the KAFO to assist swing out of the affected limb only. |
| 14 | Cane and AFO are used. Therapist assists in shifting the center of gravity 2 out of 3 gait cycles, only when the affected limb cannot swing out. No assistance is required for stance of the affected limb. |
| 15 | For the purpose to assist swing and stance of the affected limb, therapist holds the pelvis on the affected side and prompts hip joint movement. AFO is used. |
| 16 | Therapist uses a weak force to prevent pelvis drift 1 out of 5 gait cycles during stance of the affected limb. AFO is used. No assistance is required for swing out of the affected limb. |
| 17 | Cane and AFO are used. Therapist holds the pelvis from both sides and uses a weak force to assist swing out of the affected limb and assist in shifting of the center of gravity, so that the knee does not buckle during stance. |
| 18 | Cane and KAFO are used. Therapist holds the pelvis from both sides and uses a strong force to assist swing out of the affected limb and left-right shifting of the center of gravity in stance. |
| 19 | Therapist uses a weak force to prevent pelvis drift 2 out of 3 gait cycles during stance of the affected limb. AFO is used. No assistance is required for swing out of the affected limb. |
| 20 | Cane and AFO are used. Therapist assists in shifting the center of gravity 1 out of 5 gait cycles only when the affected limb cannot swing out. No assistance is required for stance of the affected limb. |

Abbreviations: KAFO, knee-ankle-foot orthosis; AFO, ankle-foot orthosis.

## Results

### 1. Development of GAA

The results of questionnaire survey are shown in Table 3 and Figure 1. Figure 1 shows the mean values for each of the questionnaires in ascending order. The amount of movement performed by the patient was less than 25% in two items (Questions 1 and 11), 25%

**Table 2.** Subject characteristics.

| | | | |
|---|---|---|---|
| Number of patients | (*n*) | 61 | |
| Age | (years) | 69.1±11.7 | [70] |
| Sex (male/female) | (*n*) | 35/26 | |
| Diagnosis (cerebral infarction/cerebral hemorrhage/ subarachnoid hemorrhage) | (*n*) | 37/15/9 | |
| Number of onset (primary/relapse) | (*n*) | 43/18 | |
| Affected side (right/left/bilateral) | (*n*) | 24/29/8 | |
| Orthosis used when walking (KAFO/AFO/none) | (*n*) | 11/16/34 | |
| Duration after onset | (days) | 76.3±45.1 | [69] |
| Hospitalization period | (days) | 40.3±33.1 | [29] |

Mean±standard deviation [median].
Abbreviations: KAFO, knee-ankle-foot orthosis; AFO, ankle-foot orthosis.

or above and less than 50% in 5 items (Questions 2, 3, 7, 13 and 18), 50% or above and less than 75% in 5 items (Questions 10, 12, 14, 15 and 17), 75% or above and less than 100% in 8 items (Questions 4, 5, 6, 8, 9, 16, 19 and 20).

As questions that were closet to 12.5%, 37.5%, 62.5% and 87.5%, Question 11 was selected as the concrete example for GAA1, Question 2 for GAA2, Question 15 for GAA3, and Question 6 for GAA4 (Table 4).

**2. Verification of reliability and validity of GAA**

The results of assessment using GAA by assessors A and B are shown in Table 5. The $\kappa$ coefficient was 0.76, and weighted $\kappa$ coefficient was 0.96, showing high inter-rater reliability. The mean values of FAC score, FIM-walk score, maximum walking speed, FIM-M score, and SIAS-L/E score are shown in Table 6. The correlation coefficients of GAA scores (assessor A) versus the above assessments were as follows: 0.95 for FAC scores (Figure 2), 0.95 for FIM-walk scores (Figure 3), 0.82 for maximum walking speed (Figure 4), 0.89 for FIM-M scores (Figure 5), and 0.61 or SIAS-L/E scores (Figure 6); all of which showed a significant correlation.

**Discussion**

The purpose of this study was to develop a new gait ability assessment method, the GAA, to accurately capture the changes in gait independence by utilizing the FIM scoring criteria, and to verify the inter-rater reliability and validity of GAA. The results of verification suggest that when used in patients with
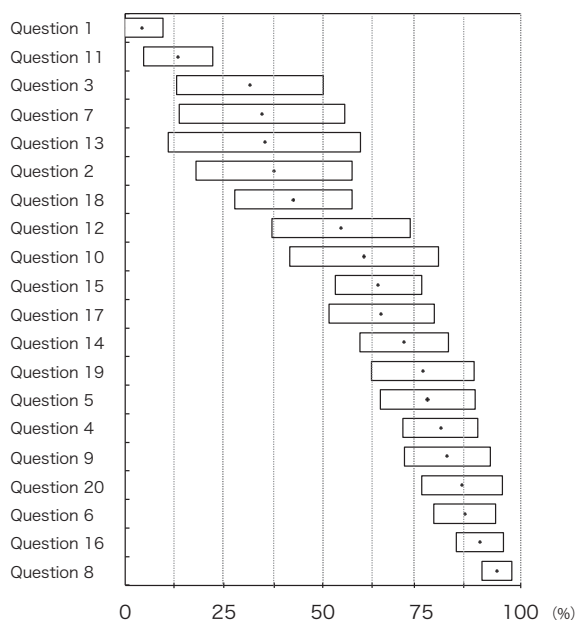


**Figure 1.** Mean and standard deviation for the questionnaire items (in ascending order).
Point denotes mean percent and box denotes standard deviation.

**Table 3.** Mean (%) and standard deviation for the questionnaire items.

| Question no. | Mean (%) | Standard deviation (%) | Question no. | Mean (%) | Standard deviation (%) |
|---|---|---|---|---|---|
| Question 1 | 4.2 | 5.3 | Question 11 | 13.5 | 8.8 |
| Question 2 | 37.7 | 19.8 | Question 12 | 54.6 | 17.5 |
| Question 3 | 31.5 | 18.5 | Question 13 | 35.2 | 24.3 |
| Question 4 | 79.7 | 9.5 | Question 14 | 70.6 | 11.2 |
| Question 5 | 76.5 | 12.0 | Question 15 | 64.1 | 11.0 |
| Question 6 | 85.9 | 7.8 | Question 16 | 89.7 | 6.0 |
| Question 7 | 34.6 | 21.0 | Question 17 | 64.8 | 13.3 |
| Question 8 | 94.1 | 3.8 | Question 18 | 42.5 | 14.8 |
| Question 9 | 81.5 | 10.9 | Question 19 | 75.3 | 13.0 |
| Question 10 | 60.5 | 18.8 | Question 20 | 85.2 | 10.3 |

**Table 4.** Evaluation criteria for Gait Ability Assessment for hemiplegics (GAA).

| Score | Amount of assistance | Remark or concrete example |
|---|---|---|
| 7 | 0% | Complete independence |
| 6 | 0% | Modified independence |
| 5b | 0% | Supervision (distant) |
| 5a | 0% | Supervision (close) |
| 4 | 0%<amount of assistance≤25% | Therapist uses a weak force to prevent pelvis drift 1 out of 3 gait cycles during stance of the affected limb. AFO is used. No assistance is required for swing out of the affected limb. |
| 3 | 25%<amount of assistance≤50% | For the purpose to assist swing and stance of the affected limb, therapist holds the pelvis on the affected side and prompts hip joint movement. AFO is used. |
| 2 | 50%<amount of assistance≤75% | Cane and AFO are used. Therapist holds the pelvis from both sides, and uses a strong force to assist swing out of the affected limb and assist in shifting of the center of gravity, so that the knee does not buckle during stance. |
| 1 | 75%<amount of assistance | Therapist raises the upper body from the back, holds the thigh cuff of the KAFO to swing out the affected limb, and assists the trunk and hip joint even in stance. The patient can operate a cane. |

Abbreviations: KAFO, knee-ankle-foot orthosis; AFO, ankle-foot orthosis.

**Table 5.** Contingency table of GAA scores assessed by the two assessors.

| | | Assessor B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 |
| Assessor A | 1 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 0 | 1 | 4 | 1 | 0 | 0 | 0 | 0 |
| | 4 | 0 | 0 | 1 | 8 | 0 | 0 | 0 | 0 |
| | 5a | 0 | 0 | 0 | 2 | 19 | 2 | 0 | 0 |
| | 5b | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | 6 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 |
| | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |

**Table 6.** Results of various assessment methods.

| | | | |
|---|---|---|---|
| FAC score | (points) | 2.8±1.2 | [3] |
| FIM-walk score | (points) | 4.6±1.8 | [5] |
| Maximum walking speed | (m/min) | 34.4±32.6 | [21.4] |
| FIM-M score | (points) | 56.0±22.2 | [57] |
| SIAS-L/E score | (points) | 8.5±4.2 | [9] |

Mean±standard deviation [median].

stroke, GAA has high inter-rater reliability and has validity as a gait ability assessment method.

First, the development of GAA will be discussed. The draft concrete descriptions proposed by two physical therapists and two rehabilitation medical specialists with more than 10 years of experience in stroke rehabilitation are expected to have a certain degree of validity as concrete examples commonly experienced clinically.

In the questionnaire survey responded by physical therapists with 8 or more years of experience, the mean amount of assistance in the concrete examples selected for GAA1 to GAA4 differed from the optimum value for each item (12.5, 37.5%, 62.5%, 87.5%) by only 0.2 to 1.6%, indicating that appropriate concrete examples were selected for each of the items.

Next, the reliability and validity and GAA will be discussed. The subjects of this study were patients who were hospitalized in the comprehensive inpatient rehabilitation wards, whose gait ability were changing over time. In order to accurately verify the inter-rater reliability, the dates of assessment by the two assessors should be as close as possible. In this protocol, assessors A and B assessed the subjects using GAA on the same day. Therefore, we judge that there is no need to consider subjects' gait ability improvement.

In general, the value of $\kappa$ coefficient is interpreted in terms of strength of agreement as follows: 0.21 to 0.40 as fair, 0.41 to 0.60 as moderate, 0.61 to 0.80 as substantial, and 0.81 to 1.00 as almost perfect [16]. The $\kappa$ coefficient of inter-rater reliability of FAC in stroke patients was reported to be 0.72 by Holden et al.
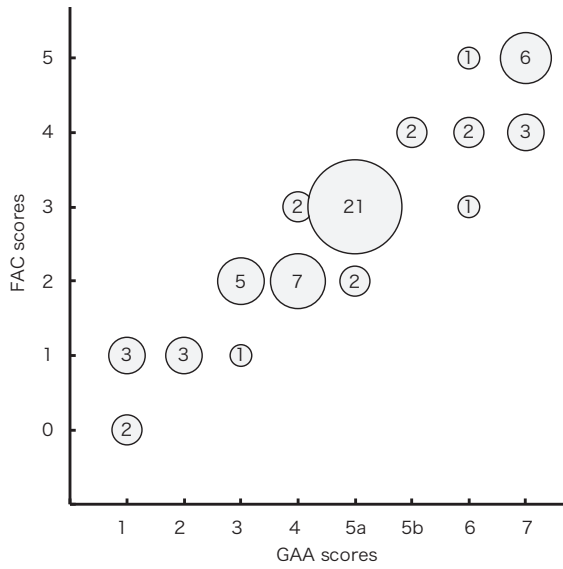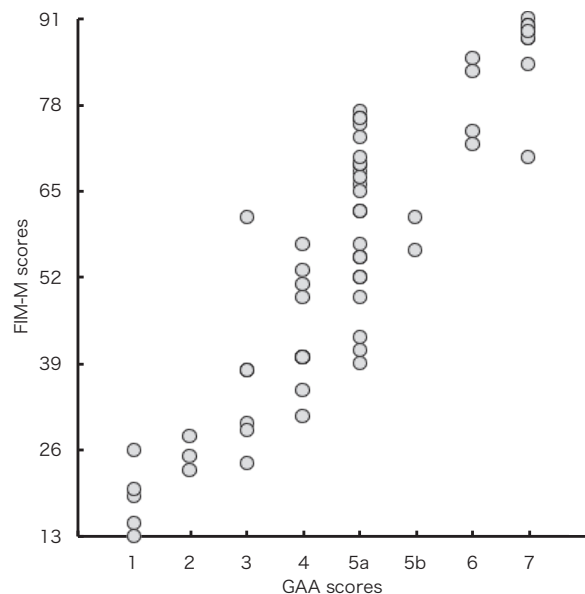
**Figure 2.** Scatter plot between GAA scores and FAC scores.
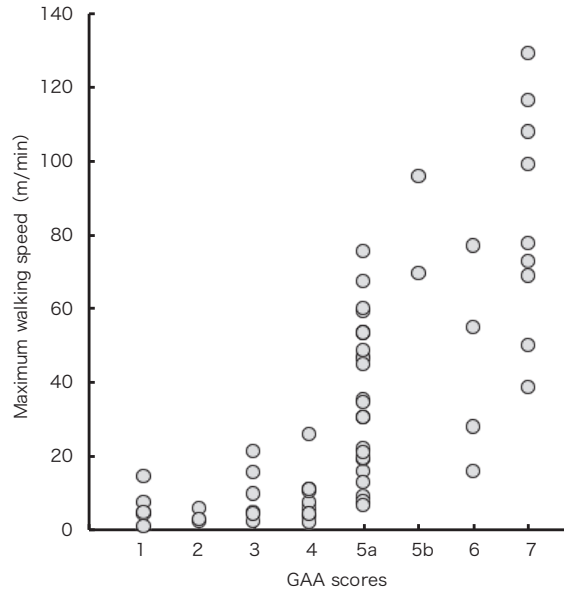


**Figure 4.** Scatter plot between GAA scores and maximum walking speed.
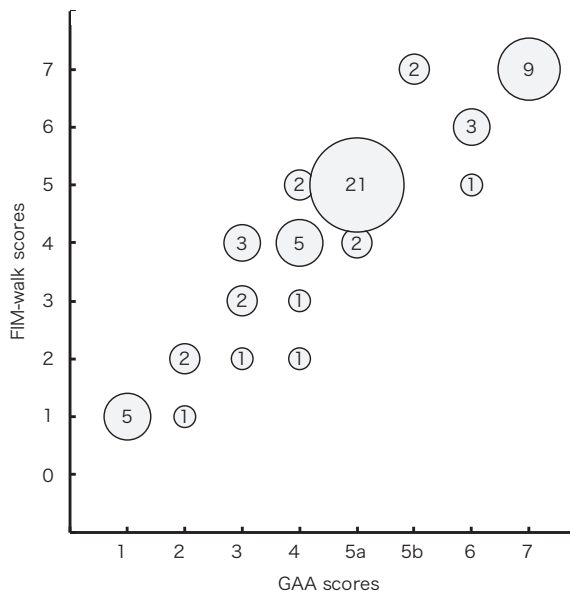


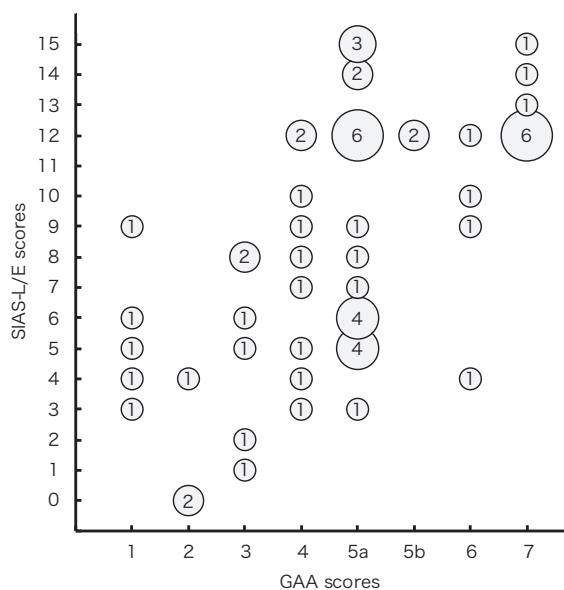**Figure 3.** Scatter plot between GAA scores and FIM-walk scores.



**Figure 5.** Scatter plot between GAA scores and FIM-M scores.

[10] and 0.91 by Mehrholz et al. [17]. Hamilton et al. [18] studied the inter-rater reliability of individual FIM motor items, and reported that $\kappa$ coefficients ranged from 0.54 to 0.66, and that $\kappa$ coefficients improved to 0.71 to 0.84 in facilities fulfilling four more stringent reliability criteria. The $\kappa$ coefficient for GAA was 0.76 and weighted $\kappa$ coefficient was 0.96, which were equal to or higher than the assessment methods with confirmed reliability, indicating that the inter-rater reliability is high overall.

GAA2 scores had 3 cases of perfect match and 3 cases of 1 point difference, and GAA5b score had 1 case of perfect match and 3 cases of 1 point difference, showing a tendency of lower concordance rate

compared with other GAA scores. The concrete example of GAA2 is "Cane and AFO are used. Therapist holds the pelvis from both sides, and uses a strong force to assist swing out of the affected limb and assist in shifting of the center of gravity, so that the knee does not buckle during stance." Although the expression "a strong force" is considered to be effective to express the degree of assistance, but it is possible that perception of the degree may differ between assessors. On the other hand, GAA5b is distant supervision, and no concrete example is provided for the discrimination from GAA6 which is modified independence, and it is possible that the concordance rate was low because it was left to the

**Figure 6.** Scatter plot between GAA scores and SIAS-L/E scores.

overall judgment of the assessor.

GAA scores correlated significantly with both FAC and FIM-walk scores, which are the existing gait ability assessment methods, confirming that GAA has criterion-related validity. GAA is a scale specialized for post-stroke patients, which standardizes the amount of gait assistance based on the concept of scoring criteria for the amount of assistance in FIM, and illustrates with concrete examples. GAA is evaluated on an 8-point scale including 5a and 5b, while FAC is evaluated on a 6-point scale. Previous study has pointed out that FAC has the issue of low responsiveness in people with low gait ability [12], and this may have an effect when used in post-stroke patients with various levels of gait ability. In addition, the scoring criteria for FIM-walk include the element of walking distance. While this test appropriately reflects the activities of daily living, it may deviate from the gait ability observed in gait training and gait assessment settings. GAA is useful in that it can capture pure gait ability, and therefore may be used in different contexts according to the purpose of assessment.

Next, the relationship of GAA with the motor function of the affected lower limb, ADL ability, and maximum walking speed will be described. The FIM-M score and SIAS-L/E score (total score of lower limb items in SIAS) used in the present study are both assessments tools with confirmed reliability and validity, and both showed a high correlation with GAA. We thus consider the validity of GAA to be high.

When considering the practicality of an assessment method, the required human resources, time, equipment, space, and characteristics of target patients

become issues. Although it depends on the severity of the patient subject, GAA can be performed by one assessor in approximately 10 minutes including preparation time. In addition, the only equipment required for GAA is assist devices and orthoses necessary for walking, and the assessment can be performed as long as if there is space for walking. From these facts, we consider that GAA is highly practical. Furthermore, the present study included all patients diagnosed with stroke regardless of recurrence, medical history, complications, and lesions, and the scope of application of GAA is considered to be wide.

In the future, we plan to use GAA as a gait ability assessment method not only in research but also in clinical setting, such as to prove therapeutic effect and predict outcome.

## Study limitation

It should be noted that this study was conducted in a single institution with a small number of patients, and it was not possible to examine inter-rater reliability and criterion-related validity for all the diverse gait patterns exhibited by post-stroke patients.

## Conclusion

We developed the GAA, a new gait ability assessment method, aiming to accurately track changes in gait independence by utilizing the scoring criteria of FIM. The inter-rater reliability of GAA verified by two physical therapists was high. In addition, the criteria-related validity of GAA was confirmed by comparing with the existing walking ability assessment methods: FAC, FIM-walk, and maximum walking speed; and a high correlation with FIM-M and SIAS-L/E was also revealed. GAA does not require any special equipment and can be performed in a limited space, and is therefore considered to be highly practical. In the future, GAA is potentially useful as a gait ability assessment method not only in research but also in clinical setting, such as for proving therapeutic effect and predicting outcome.

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