INTRODUCTION

Although many patients with acute stroke have limited physical function and basic mobility limitations, appropriate management of patients in a stroke unit promotes their functional recovery. Early mobilization, with an emphasis on out-of-bed interventions is an important component of stroke unit care. However, to our knowledge, only a few methods of assessment have been shown to screen stroke-related impairments and disabilities in patients while they are still on bed. We sought to establish the validity and reliability of a newly developed Functional Bridge Test (FBT) for hemiplegic patients with acute stroke.

Methods: This repeated-measures, observational study was conducted at a stroke care unit at an acute hospital. We assessed the validity of the FBT score, intra-rater and inter-rater reliabilities of the FBT, and concurrent validity of the FBT in stroke patients with hemiplegia. In addition to the original qualitative assessment, the FBT was also assessed quantitatively to evaluate the validity of the FBT score. Outcome measures included stroke severity, lower limb muscle strength, and basic mobility.

Results: We enrolled 32 patients with acute stroke. The newly developed FBT score had high validity. Intra-rater and inter-rater reliabilities (weighted kappa coefficient, 95% confidence interval) showed almost perfect agreement (0.95, 0.88–1.00; 0.98, 0.94–1.00, respectively). The FBT score was significantly associated with stroke severity, physical function, and basic mobility.

Conclusions: The FBT has sufficient validity and reliability for acute stroke patients with hemiplegia. The advantages of the FBT in a clinical setting are based on its ability to be quickly administered on a bed without the need for specialized equipment. The FBT may help in screening functional impairment and disability in hemiplegic patients with acute stroke before they resume out-of-bed activities.
stay after a stroke, but the time spent upright remained low throughout the study’s observation period. In addition, the activity levels in patients after an acute stroke were reported to vary among hospitals. These findings indicate a need to standardize interventions aimed at resuming out-of-bed activities.

To provide a safe and appropriate out-of-bed program, patients need to be screened for stroke-related functional impairments and disabilities in advance. However, only a few conventional assessments can be completed before patients resume out-of-bed activities. Moreover, there are several limitations to assessing patients with acute stroke; these include blood pressure changes, consciousness disorders, attention disorders, difficulty in maintaining a posture, low endurance, and medical treatments.

Therefore, we have developed a novel Functional Bridge Test (FBT), which involves the patient making a bridge movement while in the supine position on the bed. The bridge movement is elevation of the hips and trunk extension under gravity, and requires muscle activities of the hip and trunk extensors. Other studies have used the bridge movement to evaluate the patient’s functional ability, lumbar spine-stabilization capability, and cardiopulmonary function. The bridge maneuver may reflect the postural control function of proximal lower-extremity muscles and the trunk muscles required to get out of bed.

This study aimed to investigate the effectiveness of the FBT to screen impairments and disabilities in hemiplegic patients with acute stroke. The specific aims of the study were to determine the validity of the FBT score by quantitative evaluation, the intra- and inter-rater reliability of the FBT, and the concurrent validity of the FBT. We hypothesized that the FBT would show high reliability and would significantly correlate with scores of physical functions (stroke severity, lower limb hemiplegia, and lower extremity muscle strength) and basic mobility in hemiplegic patients with acute stroke.

**METHODS**

**Study Design**

This prospective, single-center study used a repeated-measures, observational design to investigate the validity of the FBT score, reliability of the FBT, and concurrent validity of the FBT. The study was explained to all patients, after which we obtained written informed consent from all participants. This study was approved by the Ethics Review Board of the Nippon Medical School Chiba Hokusoh Hospital (Approval number: 760) and was conducted in accordance with the principles of the Declaration of Helsinki.

**Study Population**

This study was conducted on all patients who were consecutively admitted to the stroke care unit at the Nippon Medical School Chiba Hokusoh Hospital from September 2019 to March 2021 and who were diagnosed with a stroke (except subarachnoid hemorrhage and bleeding from an arteriovenous malformation) based on neurological symptoms and X-ray computed tomography or magnetic resonance imaging. Patients eligible for participation in this study were those with acute stroke who were recruited within 10 days of onset of the stroke. Inclusion criteria were as follows: aged 20 years or older, no previous history of stroke, lower limb hemiplegia, awake or able to open eyes when wakened verbally, and the ability to independently perform activities of daily living (ADL) prior to the stroke. The following exclusion criteria were applied: insufficient comprehension or collaboration because of aphasia and/or cognitive dysfunction; progressive neurological disorders identified during the assessment period; previous cranial nerve disease; lesions on both sides of the cerebral hemisphere; ataxia of the lower limbs; a history of lower extremity amputation; and difficulty performing a bridge maneuver because of a disorder other than stroke (such as orthopedic disorders or unstable medical conditions). In this study, the sample size was set to 32 patients because we graded the FBT on four levels.

**Raters**

We developed a novel FBT for clinical use by physiotherapists with various levels of clinical experience. Accordingly, we selected two physical therapists with different clinical experience to act as raters: rater A had 7 years of clinical experience, and rater B had 2 years of clinical experience. Rater A created a manual regarding the standardized evaluation of the FBT. Rater B was familiarized with the FBT via a 10-minute session before the start of this study, during which rater A explained and demonstrated the FBT procedure using the standardized set of instructions.

**Procedure**

Each patient was tested three times (labeled Days 1, 2, and 3). Tests were conducted on consecutive days or at a maximum of 2 days apart, ensuring that each patient’s test data were collected within 1 week. Three test occasions were used to allow for the possibility of a learning effect between Days 1 and 2. On Day 1, the patients were introduced and habituated to the FBT, whereas data collected on Days 2 and
3 were used for analysis. The validity of the FBT score was examined using the FBT score on Day 2 and two-dimensional data from video recorded during the FBT on Day 2. The intra-rater reliability was calculated by comparing the FBT score evaluated by the same rater (rater A) on Days 2 and 3. The inter-rater reliability was calculated for differences between raters A and B on Day 3. Then, the concurrent validity was calculated for the correlation between the FBT score and other outcomes on Day 2.

On the first test day, the FBT was administered by rater A. The FBT procedure was first explained to the patient by the rater according to the standardized set of instructions. Each patient then performed one trial of the FBT. On the second test day, the FBT was again administered by rater A, who was blinded to the previous evaluation results. Patients underwent the FBT only once on Day 2, although other outcome parameters were also measured. On the third and final test day, the patients performed two sets of the FBT; one set was administered by rater A (who was blinded to the previous evaluation results), whereas the other was supervised by rater B. Raters were blinded to each other’s findings. Patients performed the FBT once for each rater.

Outcome Measures
Characteristics of Patients
We recorded the patient demographic variables of age, sex, height, weight, and time of evaluation from the onset of stroke. The stroke details were also recorded, such as the type of stroke (infarction or hemorrhage), the side of hemiplegia, stroke severity according to the National Institutes of Health Stroke Scale (NIHSS) score,19 the motor score for the leg on the affected side (NIHSS Subtest), and the modified Rankin Scale (mRS)20 as a measure of global outcome after stroke.

Functional Bridge Test
The main outcome measurement was the FBT, which we had developed for on-bed assessment of the patient’s ability to raise and hold the hips for 3 seconds (Fig. 1). The starting position for the FBT required the patient in the supine position on a bed with the arms folded across the chest and the knees flexed at 120°. The rater supports the patient’s foot and knee on the affected side. If the patient collapses to the affected side during the bridge maneuver, the rater does not add any additional knee support. (b) The lift-off position of the FBT. The patient strives to hold the hips raised at a maximum height for 3 seconds.

![Image of Functional Bridge Test](image-url)

**Fig. 1.** The Functional Bridge Test (FBT). (a) The starting position of the FBT. The patient lies in the supine position on a bed with arms folded across the chest and the knees flexed at 120°. The rater supports the patient’s foot and knee on the affected side. If the patient collapses to the affected side during the bridge maneuver, the rater does not add any additional knee support. (b) The lift-off position of the FBT. The patient strives to hold the hips raised at a maximum height for 3 seconds.
surement of the height of the lowest part of the hip on the affected side. The rater used his or her hand to evaluate the minimum grading of the hip, while counting to three, using a four-point grading scale after the hip had been elevated to the maximum height. Grade 1 was defined as a difficulty in lift-off (less than 3 seconds). Grade 2 was defined as lift-off for 3 seconds or more, with insufficient hip elevation [higher than or equal to the height of a hand on the bed (approximately 2 cm high)]. Grade 3 was defined as lift-off for 3 seconds or more, with slightly insufficient hip elevation [higher than or equal to a vertical fist on the bed (approximately 8 cm high)]. Grade 4 was defined as lift-off for 3 seconds or more, with sufficient hip elevation [higher than or equal to the distance from the tip of the index finger that was positioned with finger abduction and the intermediate forearm to the bed (approximately 14 cm high)]. These hand-based measures use to evaluate the height of the lowest part of the hip are shown in Fig. 2.

Although the FBT was originally designed as a qualitative evaluation, this study also used a quantitative evaluation to verify the validity of the FBT score based on the manual measurement. Quantitative evaluation was performed using videos recorded during the FBT performed on Day 2. A video camera (HC-W570M; Panasonic, Osaka, Japan) was positioned on a tripod 120 cm from the anterior superior iliac spine on the affected side. In addition, an inclinometer (GL-300; Nippon Seiki, Nagaoka, Japan) was used to maintain the video camera in a plane parallel to the floor at a height of 60 cm. Prior to performing the maneuver, reflective markers were placed on the patient’s acromial angle, crista iliaca (between the anterior superior iliac spine and the posterior superior iliac spine), anterior superior iliac spine, greater trochanter of the femur, and lateral condyle of the femur on the affected side. These markers were used to analyze the hip elevation and hip joint angle via a two-dimensional video analysis (Kinovea two-dimensional video software, Version 0.8.26; https://www.kinovea.org/). The elevation of the hip was defined as the lowest height of the hip within 2 seconds of when the maximum height was reached. A larger hip elevation indicated that the patient had higher bridge function. The height of the hip elevation was determined using the reflective marker on the anterior superior iliac spine. The anterior superior iliac spine at rest was set to 0 cm. The hip joint angle was defined as the maximum hip joint angle within 2 seconds of when the maximum height was reached. A smaller hip joint angle indicated that the patient had higher bridge function. The hip joint angle was determined using the angle formed by the line connecting the acromion angle and the crista iliaca with the line connecting the greater trochanter of the femur and the lateral condyle of the femur.

Prior to this study, a preliminary study was conducted to validate the platform bed (Fig. 1) used in present test. The FBT scores for the ordinary bed (used by patients in hospital wards) and scores for the platform bed showed excellent agreement [weighted kappa coefficient=0.91; 95% confidence interval (CI), 0.85–0.97; P <0.001]. The platform bed was used in the present study because of its consistency with the ordinary bed and for reasons of accuracy in video recording.

**Short Form of Postural Assessment Scale for Stroke Patients**

We used the Short Form of the Postural Assessment Scale for Stroke patients (SFPASS)21) to evaluate the basic mobility of each patient. The SFPASS is a shortened version of the
PASS and has good reliability, validity, and responsiveness. The SFPASS consists of five items: moving from sitting to supine, supine to sitting, sitting to standing, standing to sitting, and one-leg stance on the non-paralyzed leg. The ability to perform each item is graded on a three-level scale. The total score ranges from 0 to 15, with higher scores indicating a greater postural control ability. As a measurement condition for this study, the affected side of the patient was located at the edge of the bed, which was 43 cm high and did not have handrails.

Muscle Strength of Lower Limb

Isometric muscle strength of the knee and hip extensor was assessed on both legs with a hand-held dynamometer (μTas F-1; Anima, Tokyo, Japan). The patients were tested with standardized testing positions and dynamometer placements. Given that some patients were not stable in the sitting position, all measurements were repeated in the supine position. The measurements of knee extensor and hip extensor isometric strength by hand-held dynamometer in neurologically affected patients have been reported as reliable (intra-class correlation coefficient: 0.87–0.99). The test was performed twice and mean values were obtained. A third trial was performed when the difference between the two measurements exceeded 10%. The test parameters involved calculating the torque to body weight ratio (Nm/kg) and the percentage of body weight (%). The former was calculated by multiplying strength (N) by lever arm length (m), divided by body weight (kg). The latter was calculated by dividing strength (N) by body weight (N), multiplied by 100 (%). The muscle strength on the affected and unaffected sides combined was estimated as the sum of the test parameters on both legs.

Statistical Analysis

All statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 26.0 for Windows (IBM, Armonk, NY, USA), and the threshold for significance was P <0.05. Data were analyzed in three stages: validity of the FBT score, reliability, and concurrent validity.

First, to examine the validity of the FBT score in patients with acute stroke, one-way analysis of variance and Tukey’s honestly significant difference test were used to determine the difference between the FBT score and the quantitative FBT data. The value of the quantitative evaluation was presented for each bridging ability classified by the FBT score. Second, the intra-rater and inter-rater reliabilities were assessed using weighted Cohen’s kappa (quadratic weight).

The levels of the kappa coefficient (κ) were classified using the Landis standards: fair agreement, 0.21–0.40; moderate agreement, 0.41–0.60; substantial agreement, 0.61–0.80; and near-perfect agreement, ≥0.81. Last, the concurrent validity was evaluated using Spearman’s rank correlation coefficient (ρ), which tested the relationship between the FBT score and the NIHSS score, the motor score of the leg on the affected side (NIHSS Subtest), the lower limb muscle strength, and the SFPASS score.

RESULTS

Characteristics

Of the 291 consecutive patients with acute stroke admitted during the study period, 32 patients were included in the analysis based on the inclusion and exclusion criteria. No data were missing. Table 1 shows the demographic and clinical characteristics of the study participants. The mean duration from stroke onset to Day 1, Day 2, and Day 3 were 5.1 days (SD=2.2), 6.7 days (SD=2.3), and 8.7 days (SD=2.5), respectively.

Validity of FBT Score

The quantitative data in each FBT score are presented in Fig. 4. The hip elevation and hip joint angle revealed significantly higher bridge function with higher FBT scores. The mean hip elevation in each grade was as follows: Grade 1, −0.8 cm (SD=1.6); Grade 2, 3.7 cm (SD=1.1); Grade 3, 9.0 cm (SD=1.5); and Grade 4, 15.2 cm (SD=1.8). The mean hip joint angle in each grade was as follows: Grade 1, 56.4° (SD=7.5); Grade 2, 44.6° (SD=4.3); Grade 3, 32.4° (SD=7.0); and Grade 4, 17.7° (SD=5.5).

Reliability

The weighted kappa coefficient for intra-rater reliability was 0.95 (95% CI, 0.88–1.00; P <0.001), indicating almost perfect agreement. Similarly, the weighted kappa coefficient for inter-rater reliability was 0.98 (95% CI, 0.94–1.00; P <0.001), also indicating strong agreement.

Concurrent Validity

The relationships between the FBT score and other variables are presented in Table 2. A higher FBT score was significantly associated with lower stroke severity, higher physical function, and higher basic mobility.
This study investigated the effectiveness of the new FBT scale for screening stroke-related functional impairments and disabilities in hemiplegic patients with acute stroke before they resume out-of-bed activities. The results showed that the FBT had high validity and reliability. Our findings suggest that the FBT is a sound psychometrical measurement tool for screening physical functions and basic mobilities in individuals with acute hemiplegic stroke.

The validity of the FBT score, which was graded based on hand-based measurements, was tested to determine whether these handshapes could be used to grade quantitative data on bridge movements. We found that the FBT score reflected the quantitative evaluation of the bridge maneuver. Therefore, the hip elevation and hip joint angle could be differentiated according to handshape, providing validity for grading each patient’s bridge movement. Essentially, a rater could distinguish the level of a bridge movement by means of each handshape.

The lower limits of the 95% CI for intra-rater and inter-rater reliabilities were 0.88 and 0.94, respectively, which indicated that the test was very good for use in individual clinical assessment. Our result for the intra-rater reliability is consistent with that reported in a previous study of frail older adults that found the maximum height of a pelvis in two identical evaluation sessions, separated by a 48-hour interval, showed almost perfect agreement. In addition, the standard error of measurement ranged from 1.38 to 1.62 cm. This suggests that the bridge performance itself is stable, with little variation. The inter-rater reliability of the FBT was excellent, even though one rater was an inexperienced therapist and had only received a 10-minute lecture on how to administer the test. The high intra-rater and inter-rater reliabilities of the FBT may be attributed to the use of a simple method, using the rater’s handshape. A previous study reported that the reliability of a unilateral bridge maneuver was poor because of the difficulty in making a precise visual evaluation of whether the pelvis was being lowered. Although the pelvis often tilts towards the affected side during the bridge movement in hemiplegic patients, as in the unilateral bridge, the handshape-based assessment may have resulted in higher reliability.

The FBT was strongly associated with other validated and established measures of stroke severity, lower limb muscle strength, and basic mobility, indicating good concurrent validity. This may be clinically plausible because a patient who achieves higher hip elevation during the bridge move-
ment may have a higher level of physical function and mobility. In particular, the knee extensor strength on the affected and unaffected sides (combined) and the SFPASS score showed strong correlation with the FBT score. Previous studies reported that the former predicted sit-to-stand independence, while the latter was associated with the Barthel Index and the Fugl-Meyer motor test. These findings suggest that the FBT can screen patients with acute stroke hemiplegia for their level of residual function before they resume out-of-bed activities. Furthermore, a previous observational study reported that one of the reasons for not using standardized outcome measures was the length of time they took for patients to complete. However, the FBT took less than 1 minute from introduction to measurement, even in acute stroke patients with various limitations to assessment. Therefore, the FBT may be clinically useful because it not only reflects stroke-related disability and impairment but also is a simple and feasible assessment tool.

Several limitations of this study should be acknowledged. First, our results may not be generalizable to all acute stroke patients with hemiplegia. This study included a large proportion of patients with mild to moderate stroke severity and excluded patients with ataxia of the lower limbs or with orthopedic disorders. Second, although the height of the lowest part of the hip on the affected side was assessed using the rater’s handshape for clinical convenience, there may be errors because of differences in the sizes of raters’ hands and the heights of subjects. Given that hand size may vary between raters, it may be necessary to evaluate hand size, as shown in this study, before performing an assessment. In broader use of the FBT, further investigation may be necessary if the height distribution of subjects is different from that of the present study. However, the use of a clinical assessment tool without any special equipment is clinically very useful in an acute setting, where simplicity is desirable. Third, although the SFPASS was used to measure mobility and showed a strong relationship with the FBT in this study, the relationship between the FBT and actual ADL is unclear in the inpatient setting. Finally, there are differences in firmness between the ordinary bed used by patients in hospital wards and the platform bed used in this study. Although we previously confirmed high agreement of FBT scores between ordinary hospital beds and the platform bed used in the study, further validation of the FBT will be required for situations in which acute stroke patients get out of bed.

**CONCLUSION**

The results of this study suggest that the FBT is a valuable clinical tool because of its simplicity and it has sufficient validity and reliability. Currently, the timing and treatment used to assist patients to resume out-of-bed activities are based on the clinical experience of physiotherapists and nurses. The use of a standardized tool that can screen functional impairment and disability in acute stroke hemiplegic patients before they resume out-of-bed activities may help to provide safer and better optimized out-of-bed programs. Future studies on the FBT should focus on the applicability of this test to stroke patients in general and the predictive validity with regard to discharge outcomes.

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**Table 1.** Demographic and clinical characteristics of the study population

| Characteristics                                | n=32     |
|-----------------------------------------------|---------|
| Age, years                                    | 68.6 ± 12.6 |
| Sex (male/female), n                          | 17/15   |
| Type of stroke (infarction/hemorrhage), n     | 15/17   |
| Hemiplegic side (right/left), n               | 13/19   |
| Height, cm                                    | 161.4 ± 7.9 |
| Weight, kg                                    | 66.0 ± 15.1 |
| NIHSS                                         |         |
| Total score, points                           | 4.0 (2.3–8.8) |
| Motor leg with affected side, points          | 1.0 (1.0–2.0) |
| mRS, points                                   | 4.0 (4.0–5.0) |
| Knee extensor strength                        |         |
| Torque to body weight ratio, Nm/kg            |         |
| Unaffected side                               | 1.3 (0.9–1.7) |
| Affected side                                 | 0.6 (0.2–1.2) |
| Combined                                      | 1.9 (1.1–2.7) |
| Percentage of body weight, %                  |         |
| Unaffected side                               | 41.7 (30.6–49.4) |
| Affected side                                 | 17.4 (4.7–37.4) |
| Combined                                      | 61.6 (31.9–83.5) |
| Hip extensor strength                         |         |
| Torque to body weight ratio, Nm/kg            |         |
| Unaffected side                               | 1.2 (0.9–1.3) |
| Affected side                                 | 0.8 (0.4–1.2) |
| Combined                                      | 2.0 (1.3–2.5) |
| Percentage of body weight, %                  |         |
| Unaffected side                               | 34.0 (26.4–39.5) |
| Affected side                                 | 24.0 (12.0–34.0) |
| Combined                                      | 57.0 (36.1–72.8) |
| SFPASS, points                                | 12.0 (3.4–13.5) |

Data are given as mean ± SD, number, or median (interquartile range).
The authors report no conflicts of interest.

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