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Original Article

Characteristics of patients with hemiparetic stroke who yield highly reliable muscle strength measurements

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Abstract. [Purpose] Accurate measurement of unaffected lower extremity muscle strength on the unaffected side is useful in patients with hemiparetic stroke; however, muscle strength measurement results in patients with hemiparetic stroke vary greatly compared with those in healthy individuals. The objective of the present study was to determine the characteristics of patients with hemiparetic stroke who yield highly reliable muscle strength measurements. [Subjects and Methods] The subjects were 55 incipient patients with hemiparetic stroke. Muscle strength was measured twice. Based on the measured changes and on error ranges in repeated measurements in previous studies, the subjects were divided into two groups: subjects whose measurement results were within the acceptable range, and those whose measurement results were not within the acceptable range. Logistic regression analysis was performed with this separation of groups as the dependent variable, and demographic data, physical functioning, and functional independence measure (FIM) as independent variables. [Results] From the analysis results, the FIM cognitive subscore was selected as a criterion for patient selection; the cutoff score was 19. [Conclusion] The results of the present study indicated that muscle strength measurements were highly reliable in patients with hemiparetic stroke with an FIM cognitive subscore of ≥19.

Key words: Stroke, Muscle strength measurement, Reliability

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INTRODUCTION

Lower limb strength on the unaffected side is crucial because of its involvement in sit-to-stand capacity, stand-pivot-sit-transfer capacity, gait speed, gait distance, and stair ascent capacity in patients with hemiparetic stroke[1)]. Accurate measurement of the unaffected lower limb strength in patients with hemiparetic stroke is important for assessing impairment, drafting therapeutic strategies, and assessing therapeutic effects. Although manual muscle testing and hand-held dynamometers are simple to use, an isokinetic dynamometer is recommended for measuring muscle strength more reliably[2)]. Using an isokinetic dynamometer, Sole et al. reported that the smallest real difference percentage of isokinetic knee extensor muscle strength in healthy individuals was 15.07%[3)]. However, Flansbjer et al. reported that in patients with hemiparetic stroke, most of whom have a functional independence measure[4)] (FIM) motor subscore of ≥78, the smallest real difference percentage of isokinetic knee extensor muscle strength on the unaffected side is 26%, which is greater than that in healthy individuals[5)]. Thus, differences in muscle exertion in patients with hemiparetic stroke, even in high-functioning patients, are greater than that in healthy individuals, making measurements less reliable.

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Table 1. Demographic and clinical data of all subjects

Number of patients	55
Age (years)	63.8 ± 12.1
Gender (male/female)	28/27
Side of paralysis (right/left)	35/20
Time after onset (days)	35.6 ± 13.2
SIAS-L/E score	4.5 ± 4.0
FIM-M score	41.0 ± 15.4
FIM-C score	21.8 ± 8.2
FIM-COM score	8.5 ± 3.6
FIM-SC score	13.2 ± 5.3
Total units of PT and OT of intervention period	51.8 ± 7.5
Muscle strength of the first measurement (Nm)	63.6 ± 35.9

SIAS-L/E: Stroke Impairment Assessment Set Motor L/E; FIM-M: Functional Independence Measure motor subscore; FIM-C: Functional Independence Measure cognitive subscore; FIM-COM: Functional Independence Measure communication; FIM-SC: Functional Independence Measure social cognition

We have examined the types of stroke patients who demonstrate large differences in muscle exertion measurements, leading us to the discovery of a measurement to detect such patients.

SUBJECTS AND METHODS

The subjects were incipient patients with hemiparetic stroke who provided consent to participate in the present study; 55 patients remained after excluding those whose muscle strength could not be measured easily, those unable to maintain a sitting position, and those with other functional impairments (Table 1). All subjects underwent the Full-time Integrated Treatment program[6], a 7 day/week rehabilitation program of physical and occupational therapy.

The present study was approved by the institutional review board of Fujita Health University Nanakuri Memorial Hospital.

On day 2 following admission to our hospital, the patients were assessed for age, time from onset until hospitalization (hereafter, “time after onset”), and Stroke Impairment Assessment Set[7] Motor lower extremity motor subscore (SIAS-L/E), and FIM (version 3)[8]. For FIM, we calculated FIM motor (FIM-M) and FIM cognitive (FIM-C) subscores. We then further classified FIM-C into FIM communication (FIM-COM), which is the total score for comprehension and expression; and FIM social cognition (FIM-SC), which is the total score for social interaction, problem solving, and memory. Muscle strength was measured on day 2 after admission to our hospital (hereafter, “first measurement”); muscle strength was measured again (hereafter, “second measurement”) on day 9. The device used to measure muscle strength was Biodex System 3 (Biodex Medical Systems; Shirley, NY, USA); the knee on the unaffected side was extended thrice in the isokinetic mode at 30°/s. The mean peak torque across the three extensions was adopted as the value for muscle strength (Nm). In the second measurement, we examined the total time spent in physical and occupational therapy in the 1-week period after the first measurement.

In the present study, the subjects were separated into two groups based on the difference in muscle strength measurements: subjects whose difference was within the acceptable range and were thus considered able to exert muscle strength (hereafter, “Acceptable group”), and subjects whose difference was outside the acceptable range and were thus assumed to be unable or unwilling to exert muscle strength (hereafter, “Unacceptable group”).

In separating subjects into groups, the acceptable range of difference was established by combining measurement error ranges in previous studies and potential increases in muscle strength enabled by recovery rehabilitation.

The measurement error in repeated measurements with an isokinetic dynamometer in healthy subjects was assumed to be 15%[3], whereas the maximum muscle strengthening effect in 1 week (the period between the two muscle strength measurements in the present study) was assumed to be also 15%[9]. Patients who demonstrated a decrease of more than 15% or an increase of more than 30% in muscle strength from the first measurement to the second measurement were sorted into the Unacceptable group; all other subjects were sorted into the Acceptable group.

Statistical analysis was performed by using SPSS Statistics 19 (International Business Machines Corp., Armonk, NY, USA). Logistic regression analysis was performed with muscle strength measurement acceptability (Acceptable group versus Unacceptable group) as the dependent variable. The independent variables consisted of age, SIAS-L/E, FIM-M, FIM-C, muscle strength during the first measurement, and the total units of physical and occupational therapy in the 1-week intervention period. For FIM-COM and FIM-SC, logistic regression analysis was performed with forced entry. Subsequently, receiver operating characteristic (ROC) curves were drawn for both FIM-COM and FIM-SC with the selected variables; the area under the curve (AUC) was calculated, and the Youden index was used to determine the cutoff values. Basic information was

Table 2. Demographic and clinical data of the subjects stratified into two groups

	Acceptable group	Unacceptable group	
Number of patients	43	12	
Age (years)	63.7 ± 12.8	63.9 ± 10.2	
Gender (male/female)	22/21	6/6	
Side of paralysis (right/left)	26/17	9/3	
Time after onset (days)	33.3 ± 12.9	44.1 ± 10.8	*
SIAS-L/E score	4.9 ± 4.2	2.9 ± 2.8	
FIM-M score	43.2 ± 15.2	32.9 ± 13.7	*
FIM-C score	23.7 ± 7.8	14.8 ± 5.5	*
FIM-COM score	9.2 ± 3.4	5.9 ± 3.3	*
FIM-SC score	14.4 ± 5.2	8.9 ± 2.9	*
Total units of PT and OT of intervention period	52.2 ± 7.7	50.2 ± 7.1	
Muscle strength of first measurement (Nm)	68.7 ± 36.4	45.6 ± 28.7	*

*p<0.05
SIAS-L/E: Stroke Impairment Assessment Set Motor L/E; SIAS-L/E: Stroke Impairment Assessment Set Motor L/E; FIM-C: Functional Independence Measure cognitive subscore; FIM-COM: Functional Independence Measure communication; FIM-SC: Functional Independence Measure social cognition

compared between the Acceptable and Unacceptable groups by using the independent t-test.

RESULTS

Based on rates of change in muscle strength between the first and second measurements, 43 and 12 subjects were sorted into the Acceptable and Unacceptable groups, respectively. In between-group comparisons, significant differences were observed in time after onset, muscle strength during the first measurement, FIM-M, FIM-C, FIM-COM, and FIM-SC (Table 2). Forward stepwise logistic regression analysis revealed FIM-C (p<0.01) to be a significant factor in the acceptability of muscle strength measurements. Furthermore, when logistic regression analysis was performed with forced entry for FIM-COM and FIM-SC (respective detailed subsets of FIM-C), both FIM-COM (p<0.05) and FIM-SC (p<0.01) were found to be significant factors in the acceptability of muscle strength measurements. The odds ratios for FIM-C, FIM-COM, and FIM-SC were 1.196 [confidence interval: 1.057–1.353], 1.364 [confidence interval: 1.078–1.727], and 1.310 [confidence interval: 1.083–1.585], respectively. In examinations of the fits of the regression models in ROC curves, the AUC for FIM-C (Fig. 1), FIM-COM (Fig. 2), and FIM-SC (Fig. 3) was 0.828 (p<0.01), 0.767 (p<0.01), and 0.816 (p<0.01), respectively. The cutoff values based on the Youden Index for FIM-C, FIM-COM, and FIM-SC were 19, 10, and 12 points, respectively. The sensitivity for FIM-C, FIM-COM, and FIM-SC was 0.744, 0.558, and 0.651, respectively, whereas the false positive rate (1-specificity) was 0.083 for FIM-C, FIM-COM, and FIM-SC.

DISCUSSION

The results of the present study indicated that an isokinetic dynamometer yields highly reliable measurements of isokinetic knee extensor strength on the unaffected side in patients with hemiparetic stroke with an FIM-C score of ≥19.

The reliability of muscle strength measurement in patients with hemiparetic stroke is considered to involve a variety of factors, such as measurement posture stability, the effect of injury in the central nervous system on the lower extremity on the unaffected side, and cognitive function. The loss of balance in the sitting position (the position used for testing in the present study) is one of the chief complaints of patients with hemiparetic stroke; however, the isokinetic dynamometer in the present study was equipped with four belts that were used to firmly fix the subjects' trunks and thighs, thus, potentially minimizing the effect of the loss of balance in the sitting position. Patients with hemiparetic stroke also develop tendon reflex abnormalities and reduced muscle strength in the unaffected side[10)], possibly due to effect of anterior corticospinal tract. Although this effect is difficult to surmise, assuming that the degree of the effect on the unaffected side is proportional to the degree of paralysis in the affected side, the small contribution of SIAS-L/E to the sorting of patients into the Unacceptable group may signify that ipsilateral control has little effect.

Cognitive ability was indicated in the results of the present study to be more involved in the reliability of muscle strength measurement than level of paralysis or motor ability. The cognitive subscore of FIM is considered to represent cognitive ability in real life and is also considered to be highly correlated with the Adaptive Behavior Scale[11)]. In the present study, we demonstrated correct understanding of this muscle strength measurement method and the ability to perform it appropriately. In comparisons of FIM-C, FIM-COM, and FIM-SC, some results showed that all three were useful for sorting patients into

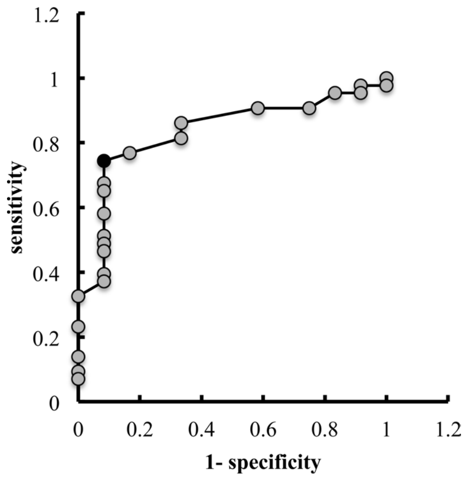

Fig. 1. ROC curve drawn using FIM-C
●Cut-off point

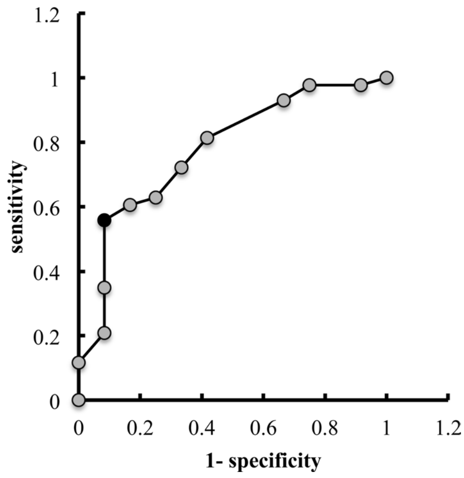

Fig. 2. ROC curve drawn using FIM-COM
●Cut-off point

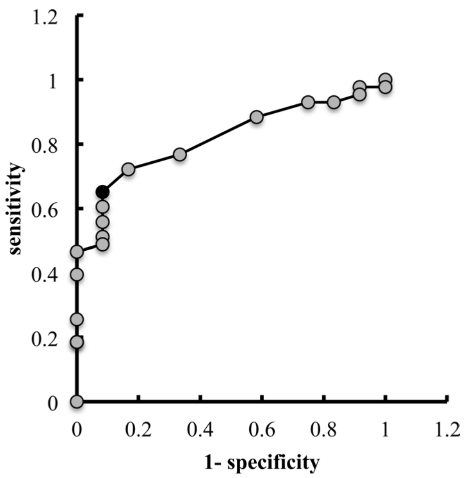

Fig. 3. ROC curve drawn using FIM-SC
●Cut-off point

the Acceptable group, whereas other results showed that FIM-COM was slightly inferior. These results demonstrated that knee extension in the present study was a simple task; and that the problem-solving ability included in FIM-SC may have been more necessary than the linguistic comprehension represented by FIM-COM.

However, discussion is necessary regarding the method wherein patients were divided into the Acceptable and Unacceptable groups. In the present study, the muscle strength increase resulting from the 1-week rehabilitation was added to the torque machine measurement error (15%); this total was used as the criterion for sorting patients into groups.

Based on Sole et al.[3)], the measurement error of repeated measurements with an isokinetic dynamometer in healthy individuals is 15.07%. In addition, de Carvalho Froufe Andrade et al.[12)] reported that the minimum detectable change in isokinetic and isometric knee flexion and extension torque ranged from 9.7% to 15% in healthy adult subjects. Impellizzeri et al.[13)] reported that the minimum detectable change in isokinetic knee extension torque, dependent differing by angular velocity, was 12.0–13.2% and 13.0–14.7% for the right and left lower extremities, respectively. Based on the results of the studies cited above, we believe that the value of 15% adopted in the present study as the error of repeated torque machine measurements was valid.

Many previous studies that have examined the reliability of repeated muscle strength measurements have used a 1-week interval before the second measurement, similar to the previous study, considering the effects of fatigue[3, 4)]. In this study, the two assessments interval was one week. Seven days per week rehabilitation was carried out during this interval. Therapy effect of muscle strengthening of this one week interval should also be considered. Although many studies have reported on the muscle strengthening effect of strength training in elderly individuals[14–16)], the study in healthy elderly individuals by

Frontera et al.[9] is particularly informative. In this study, subjects underwent a strength conditioning regimen consisting of a 10-min warm-up followed by three sets of eight repetitions at 80% of maximum muscle strength three days per week; muscle strength was reported to increase at a rate of 5% per day of training. Therefore, the maximum muscle strengthening effect yielded from 1-week rehabilitation was assumed to be 15% in the present study.

Using an isokinetic dynamometer measurement error of 15% and a 1-week rate of change in muscle strength of 15%, the subjects in the present study who demonstrated a 1-week muscle strength decrease of at least 15% or an increase of at least 30% (15% + 15%) were sorted into the Unacceptable group; based on the studies cited above, this sorting criterion is considered valid.

Two problems in all studies of patients with hemiparetic stroke (not only studies on muscle strength measurement) are whether the task is understood by the patient, and whether the task is conducted as the researcher intends. Although task performance it is generally believed to be highly reliable in patients with high cognitive ability, the level of cognitive ability wherein results can be considered reliable has no indicator. The results of the present study yielded a method of sorting patients with hemiparetic stroke based on FIM-C; this method is anticipated to be applied in the selection of patients who would yield highly reliable results not only for muscle strength measurements, but also for other types of assessments.

The present study examined the reliability of knee extension torque measurements on the unaffected side by using an isokinetic dynamometer in patients in the convalescent phase after hemiparetic stroke. Measurements were indicated to be highly reliable for patients with an FIM-C of ≥19. This method of selecting patients based on FIM-C is considered effective for patient selection in various types of research related to stroke.

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