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Original Article

Predicting FIM gain in stroke patients by adding median FIM gain stratified by FIM score at hospital admission to the explanatory variables in multiple regression analysis—An analysis of the Japan Rehabilitation Database—

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ABSTRACT
Tokunaga M, Mori Y, Ogata Y, Tanaka Y, Uchino K, Maeda Y, Kamiyoshi M. Predicting FIM gain in stroke patients by adding median FIM gain stratified by FIM score at hospital admission to the explanatory variables in multiple regression analysis —An analysis of the Japan Rehabilitation Database—. Jpn J Compr Rehabil Sci 2016; 7: 13–18.
Objective: To clarify whether the accuracy of predicting motor Functional Independence Measure (FIM) gain in stroke patients can be improved by calculating median values of motor FIM gain (median mFIM gain) stratified by motor FIM score at hospital admission, then inserting these standard gain values in multiple regression analysis.
Methods: The subjects were 2,542 stroke patients registered in the Japan Rehabilitation Database. Motor FIM score at admission was stratified into 39 groups at 2-point intervals and "median mFIM gain" was calculated for each group. With motor FIM gain as the objective variable, multiple regression analysis was performed with and without median mFIM gain in the explanatory variables. Then, correlations were examined between measured values and predicted values of motor FIM gain.
Results: Adding median mFIM gain to the explanatory variables increased the correlation coefficient of measured values and predicted values of motor FIM gain from 0.507 to 0.638.
Conclusion: Adding median mFIM gain to the explanatory variables can improve the accuracy of multiple regression analyses to predict motor FIM gain.
Keywords: Functional Independence Measure, FIM gain, multiple regression analysis, explanatory variable, stroke.

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Introduction

Multiple regression analysis has been used in stroke patients to predict Functional Independence Measure (FIM) score at hospital discharge and FIM gain (FIM score at discharge − FIM score at admission). Predicting FIM gain is more difficult than predicting FIM score at discharge. A previous study reported the mean coefficient of determination (R^2), which indicates how well explanatory variables explain the objective variable, for FIM score at discharge was 0.65, and R^2 for FIM gain was 0.22 [1].

Instead of using FIM gain, which has low prediction accuracy, in regular multiple regression analyses, we decided to calculate "standard FIM gains stratified by FIM score at admission," then insert these into multiple regression analyses to determine whether the other explanatory variables have a positive effect by producing actual FIM gain greater than the standard, or a negative effect by producing actual FIM gain less than the standard.

This study used multicenter data on stroke patients registered with the Japan Rehabilitation Database (JRD) [2]. Maximum and median FIM gain values stratified by FIM score at admission were calculated, then these "target values" or "standard values" were inserted as explanatory variables into multiple regression analyses to determine whether this improved the accuracy of predicting FIM gain.

Subjects and Methods

We used patient data from the JRD [2]. The goal behind the creation of the Japan Association of Rehabilitation Database (JARD) [3], which was established in September 2012, is to construct and use a rehabilitation database to help improve rehabilitation medicine and care. The groups which comprise JARD are: the Japanese Association of Rehabilitation Medicine, the Japanese Physical Therapy Association, the Japanese Association of Occupational Therapists, and the Japanese Association of Speech-Language-Hearing Therapists. Data on patients who have suffered stroke, hip fracture, or spinal cord injury are collected from participating institutions throughout Japan.

This epidemiological research was a retrospective study. The subjects were selected from 6,322 stroke patients registered with the JRD in April 2015 (stroke patients hospitalized in *Kaifukuki* Rehabilitation Wards). To reduce the influence of exceptional cases that could be seen as outliers, the subjects were limited to patients who fulfilled the following inclusion criteria: age 15 to 99 years, duration from onset to hospital admission of 5 to 90 days, admitted to *Kaifukuki* Rehabilitation Wards for 21 to 210 days, total score of 13 to 90 for motor FIM items (motor FIM score) at admission, FIM gain of 0 or higher, and having entries for all items to be examined. This screening obtained 2,542 subjects (Figure 1). Table 1 shows their basic characteristics.

1. Maximum and median motor FIM gain stratified by motor FIM score at admission

Motor FIM score at admission was stratified into 39 groups at 2-point intervals (13−14 points, 15−16 points, … 89−90 points). Maximum motor FIM gain (maximum mFIM gain) and median motor FIM gain (median mFIM gain) were calculated for each group.

2. Multiple regression analysis

Multiple regression analysis was performed with motor FIM gain as the objective variable and the following 5 explanatory variables (model 1): age, modified Rankin Scale (mRS) before onset, days from onset to admission, motor FIM score at admission, and total score for cognitive FIM items (cognitive FIM) at admission. Multiple regression analyses were also performed with maximum mFIM gain (model 2) and median mFIM gain (model 3) added to the explanatory variables. Mulcel [4] statistical software was used.

Correlations between measured values and predicted values of motor FIM gain in models 1 to 3 were examined with the Pearson correlation coefficient test (significance level < 5%). Residual error was also surveyed by subtracting predicted motor FIM gain from the measured values.

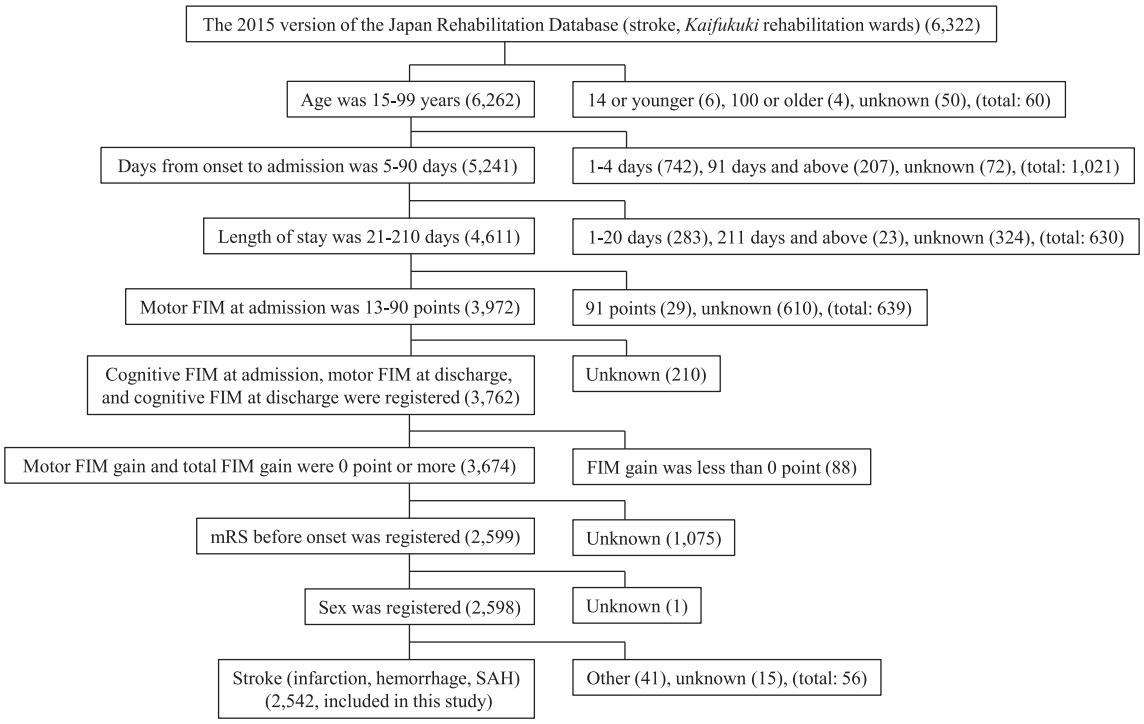

Figure 1. Inclusion and exclusion criteria.
FIM, Functional Independence Measure; mRS, modified Rankin Scale; Numerical value, number of patients.

Table 1. Basic characteristics of the subjects.

Number of patients	2,542
Sex	Male 1,492, female 1,050
Stroke type	Infarction 1,613, hemorrhage 772, SAH 157
Age	69.3 ± 12.9 (71)
mRS before onset	0.7 ± 1.4 (0)
Days from onset to hospital admission	36.3 ± 15.2 (33)
Days in the hospital	101.6 ± 44.8 (100)
Motor FIM score at admission	45.7 ± 23.2 (46)
Cognitive FIM score at admission	21.9 ± 9.0 (23)
Total FIM score at admission	67.6 ± 29.9 (69)
Motor FIM score at discharge	65.7 ± 23.1 (74)
Cognitive FIM score at discharge	25.7 ± 8.3 (28)
Total FIM score at discharge	91.4 ± 29.9 (101)
Motor FIM gain	20.0 ± 14.8 (18)

Numerical value: mean ± standard deviation or number of patients.
SAH, subarachnoid hemorrhage; FIM, Functional Independence Measure; mRS, modified Rankin Scale.

3. 2 multiple regression analyses by dividing motor FIM at admission

Motor FIM gain displayed a mountain-shaped graph with peaks around motor FIM score at admission of 25−30 points [5] and 31−36 points [6]. Thus, when FIM score at admission is inserted into a multiple regression analysis as an explanatory variable, the partial regression coefficient would be positive in patient groups with small FIM score at admission and negative in patient groups with large FIM score at admission [7]. Instead of making one prediction formula with FIM gain as the objective variable, it has been shown that the accuracy of predictions can be improved by making 2 prediction formulas by dividing FIM score at admission [8]. Therefore in the present study, we divided motor FIM score at admission into 2 groups (13−30, 31−90 points) and made 2 prediction formulas with the same 5 explanatory variables as model 1 (model 4). Similarly, we divided motor FIM score at admission into 2 groups and made 2 prediction formulas with median mFIM gain added to the explanatory variables, as in model 3 (model 5).

Results

Figure 2 shows the maximum and median mFIM gain values when motor FIM score at admission is separated into 39 groups at 2-point intervals. These figures were used in the following multiple regression analyses.

In model 1, which had age, mRS before onset, days from onset to admission, motor FIM score at admission, and cognitive FIM score at admission as explanatory variables, the coefficient of determination adjusted for degrees of freedom (R^{*2}) was 0.256 (Table 2). The measured values of motor FIM gain were positively correlated with the predicted values (correlation coefficient 0.507, $p < 0.001$). Residual error, obtained by subtracting the motor FIM gain predicted values from the measured values, was 0 ± 12.79 (mean ± standard deviation; median −0.44) (Figure 3a).

Model 2, which included "maximum mFIM gain" in the explanatory variables, showed an extremely strong correlation of −0.997 between maximum mFIM gain and motor FIM score at admission (multicollinearity). The standard partial regression coefficient, which indicates the relative strength of an explanatory variable's relationship to the objective variable, was larger for motor FIM score at admission than for maximum mFIM gain.

Model 3, which included "median mFIM gain" in the explanatory variables, produced a significant prediction formula with R^{*2} of 0.405. No correlations of 0.7 or higher were seen between the explanatory variables and all 6 explanatory variables were significant. Median mFIM gain's standard partial regression coefficient was the second largest (Table 2). The correlation coefficient between measured values and predicted values of motor FIM gain was 0.638. Residual error, obtained by subtracting the predicted values from the measured values of motor FIM gain, was 0 ± 11.43 (median −0.23) (Figure 3b).

In model 4, which divided motor FIM score at admission into a 13−30 group and a 31−90 group, the correlation coefficient was 0.641 and residual error was 0 ± 11.38 (median −0.22) (Figure 3c).

In model 5, which divided motor FIM score at admission into 2 groups and included median mFIM gain in the explanatory variables, there were extremely strong correlations between median mFIM gain and motor FIM score at admission (0.903 for 13−30 motor

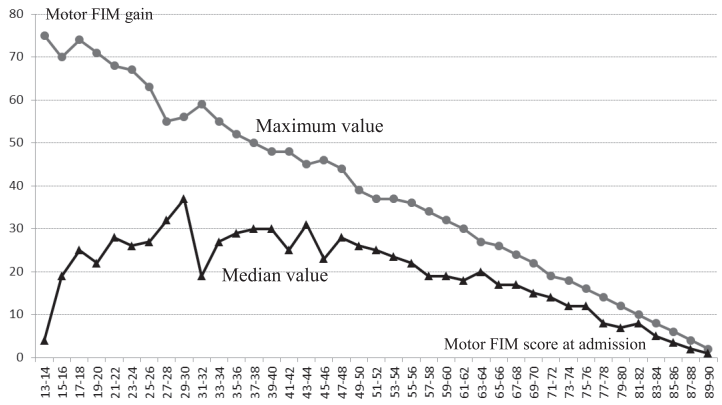

Figure 2. Maximum and median motor FIM gain stratified by motor FIM score at admission.

Table 2. Multiple regression analyses to predict motor FIM gain.

Model	Model 1	Model 3	Model 4		Model 5	
Motor FIM score at admission	13−90	13−90	13−30	31−90	13−30	31−90
Number of patients	2,542	2,542	853	1,689	853	1,689
Explanatory variables						
Age	−0.212 (−0.184)	−0.231 (−0.200)	−0.450 (−0.272)	−0.142 (−0.160)	−0.457 (−0.275)	−0.140 (−0.158)
mRS before onset	−1.528 (−0.141)	−1.391 (−0.128)	−1.493 (−0.129)	−1.233 (−0.121)	−1.388 (−0.120)	−1.161 (−0.114)
Days from onset to admission	−0.139 (−0.142)	−0.134 (−0.138)	−0.211 (−0.174)	−0.092 (−0.116)	−0.209 (−0.172)	−0.096 (−0.121)
Motor FIM score at admission	−0.410 (−0.641)	−0.271 (−0.423)	0.674 (0.196)	−0.561 (−0.768)	—	—
Cognitive FIM score at admission	0.539 (0.328)	0.311 (0.189)	0.653 (0.250)	0.194 (0.117)	0.568 (0.224)	0.136 (0.082)
Median mFIM gain	—	0.672 (0.420)	—	—	0.419 (0.244)	1.092 (0.760)
Constants	47.647	34.498	43.572	59.899	49.521	7.618
p Value	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
R^{*2}	0.256	0.405	0.31	0.508	0.326	0.517

FIM, Functional Independence Measure; mRS, modified Rankin Scale; Median mFIM gain, median motor FIM gain stratified by motor FIM score at admission.
R^{*2}, Coefficient of determination adjusted for degrees of freedom; —, Not included in explanatory variables.
Numerical value, Partial regression coefficient (standard partial regression coefficient). p Values for all explanatory variables were $p < 0.001$.

FIM score at admission, −0.920 for 31−90 motor FIM score at admission). The standard partial regression coefficient of median mFIM gain was larger than that of motor FIM score at admission, so we removed motor FIM score at admission and repeated the analyses. The standard partial regression coefficient for median mFIM gain was the second largest among the 5 explanatory variables for 13−30 motor FIM score at admission and was the largest for 31−90 motor FIM score at admission (Table 2). The correlation coefficient between measured values and predicted values of motor FIM gain was 0.651 and residual error was 0 ± 11.26 (median −0.02) (Figure 3d). Of models 1, 3, 4, and 5, this was the largest correlation coefficient and the smallest median and standard deviation of residual error.

Discussion

In the present study, we calculated maximum mFIM gain (target values) and median mFIM gain (standard values) stratified by motor FIM score at admission, and inserted these into multiple regression analyses. Maximum mFIM gain and motor FIM score at admission showed an extremely strong correlation (multicollinearity problem), and the standard partial

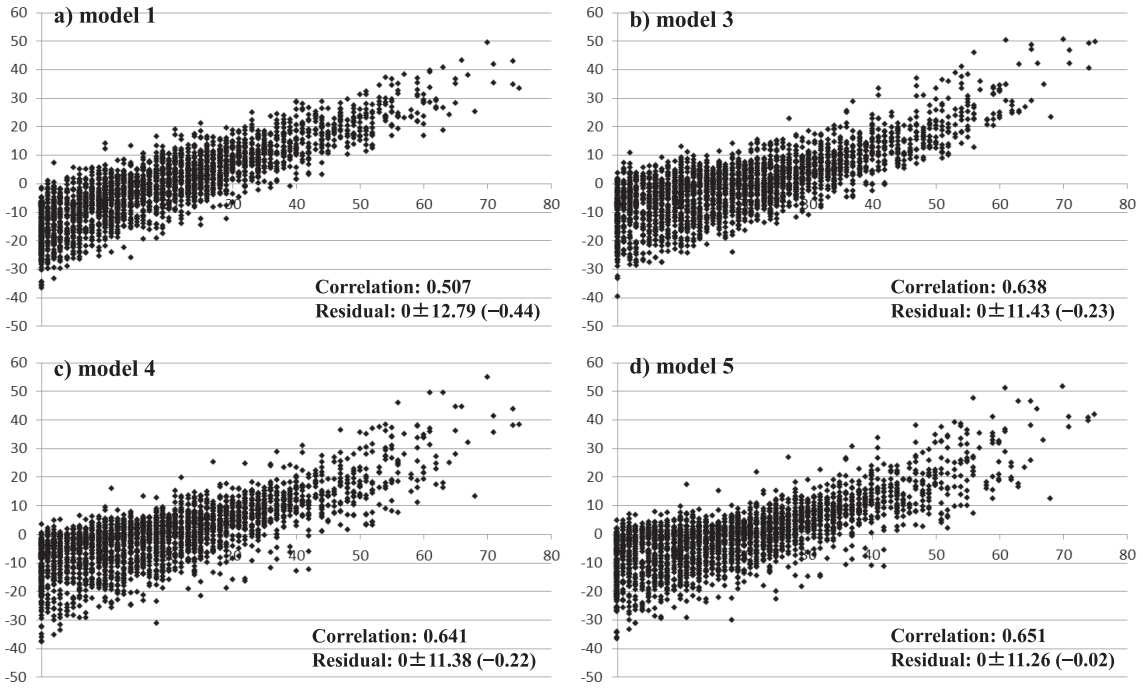

Figure 3. Relationship between measured value of motor FIM gain and residual error.
Horizontal axis, Measured value of motor FIM gain; Vertical axis, Residual error; ◇, Each patient.
Model, A detailed explanation is given in Subjects and methods; Correlation, Correlation between measured value and predicted value of motor FIM gain; Residual, Residual error, which is obtained by subtracting the predicted motor FIM gain from the measured motor FIM gain; Numerical value of the residual, mean ± standard deviation (median).

regression coefficient of motor FIM score at admission was larger than that of maximum mFIM gain. Thus, we decided that model 2, which used maximum mFIM gain, is not useful. When median mFIM gain was added to the explanatory variables, the correlation coefficient between measured values and predicted values of motor FIM gain increased from 0.507 (model 1) to 0.638 (model 3) and the median and standard deviation of residual error shrank. Moreover, when we created 2 prediction formulas by dividing motor FIM score at admission, which has been shown to increase the accuracy of predicting FIM gain [8], the correlation coefficient was 0.641 (model 4). When median mFIM gain was added to the explanatory variables and also 2 prediction formulas were created by dividing motor FIM score at admission, the correlation coefficient increased to 0.651 and the smallest median and standard deviation for residual error were obtained (model 5).

Meyer et al. [1] reviewed studies that used multiple regression analysis for functional outcome of acute-stage stroke patients. (1) They reported that of 126 explanatory variables used in 63 prediction formulas in 27 studies, 63 variables (50%) were significant. (2) Of these 63 variables, 8 were used in at least 5 formulas and were significant in at least half: FIM at admission (significant in 46 of 51 formulas), age (30/45), previous stroke (5/10), Barthel index at admission (6/6), neglect (4/6), dysphasia (4/6), impulsivity (4/6), and the National Institute of Health Stroke Scale (5/5). (3) The mean number of significant explanatory variables in the prediction formulas was 4.1 (standard deviation 2.5). Median mFIM gain was not among the 63 significant explanatory variables in their review.

In the review, the mean coefficient of determination (R^2) in 33 studies that predicted FIM score at discharge was 0.65 (min. 0.35, max. 0.82), while the mean R^2 in 20 studies that predicted FIM gain was low at 0.22 (min. 0.08, max. 0.4). In the present study, the multiple regression analysis that predicted motor FIM gain (model 1) had a coefficient of determination adjusted for degrees of freedom (R^{*2}) of 0.256. When multicenter data is used, outcomes can be impacted by differences in the quality and amount of rehabilitation provided at different hospitals [7,9,10]. This tends to make R^{*2} smaller than in analyses of single-center data. Nevertheless, the R^{*2} obtained in model 1 was close to the mean value cited in Meyer et al.'s review [1]. Note that with large numbers of explanatory variables, R^2 can be high without being useful. Therefore, when a large number of meaningless variables are used as explanatory variables, R^{*2} is obtained by correcting the number of explanatory variables and data to reduce R^2. R^{*2} is used to compare prediction formulas, and there is a $R^2 > R^{*2}$ relationship.

In model 3, which included median mFIM gain in

the explanatory variables, R^{*2} increased to 0.405, which is higher than the largest R^2 value (0.4) in the 20 studies that predicted FIM gain reviewed by Meyer et al. [1]. Selecting appropriate explanatory variables [1] and creating multiple prediction formulas [7,8,11−13] may increase the prediction accuracy of multiple regression analyses. In the present study, we found that median mFIM gain (median motor FIM gain stratified by motor FIM score at admission) was an explanatory variable that increased the accuracy of motor FIM gain predictions. We thought that "standard motor FIM gain values obtained by stratifying motor FIM at admission (median mFIM gain)" would be influenced by a number of other factors to create "measured motor FIM gain." Thus, it is easy to see why the former would be a significant explanatory variable of the latter.

This study had several limitations. First, while mean residual error (measured value − predicted value) was 0, patients with low motor FIM score at admission had negative residual error (measured value < predicted value) and patients with high motor FIM score at admission had positive residual error (measured value > predicted value). With measured motor FIM gain plotted on the horizontal axis and residual error on the vertical axis (Figure 3), the patient distribution of models 1, 3, 4, and 5 is not horizontal centered around a residual error of 0; rather it increases steadily to the right. This shows that measured motor FIM gain cannot accurately be predicted for patients on the left with gain close to 0 or patients on the right who had large gains. The slope of the increase was smaller in model 5, but there is still room for improvement. Second, while R^{*2} increased to 0.405 (model 3), it did not reach the R^2 (mean 0.65) [1] obtained when predicting FIM score at discharge. Third, median mFIM gain (Figure 2) did not form a smooth curve. Data on more patients is likely to be necessary for analyses of motor FIM score at admission in 2-point intervals. Fourth, we did not divide the subjects into a calculation group and verification group to examine the internal validity of the prediction formula using verification group data. Fifth, only hospitals that are committed to creating evidence for rehabilitation enter patient data into the JRD. Thus, the results may not reflect the average *Kaifukuki* Rehabilitation Wards in Japan.

Finding a way to make appropriate predictions for patients with FIM gain that is close to 0 or particularly large is a topic for future research.

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