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Original Article

Increasing the prediction accuracy of FIM gain by adding FIM improvement for one month from admission to the explanatory variables in multiple regression analyses

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ABSTRACT
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Objective: The coefficient of determination in multiple linear regression analyses using the gain in Functional Independence Measure (FIM) as objective variables is low. We aimed to improve the prediction accuracy of FIM gain by adding FIM improvement for one month from admission to the explanatory variables.

Methods: A total of 547 stroke patients admitted to a *Kaifukuki* (convalescent stage) rehabilitation ward were included. In multiple regression analyses using motor FIM gain as the objective variable, we created a prediction formula using only data available at admission (model 1), and a prediction formula adding FIM improvement for one month from admission (model 2). The coefficient of determination adjusted for the degrees of freedom R^{*2} and the residuals obtained by subtracting the predicted value from the measured value of motor FIM gain were investigated.

Results: The R^{*2} of model 1 was 0.364 and that of model 2 was 0.711. The residual of model 1 was 0 ± 12.3 and that of model 2 was 0 ± 8.3. In model 2, the standard deviation of the residual was reduced.

Conclusion: Adding FIM improvement for one month to the explanatory variables increased the prediction accuracy of FIM gain.

Key words: FIM gain, multiple linear regression analysis, one month from admission, explanatory variable, stroke

Introduction

Some reports have predicted activities of daily living (ADL) at discharge and ADL gain (discharge ADL − admission ADL) using multiple linear regression analyses based on a patient's basic attributes and ADL at admission. In Meyer et al.'s review of such reports [1], the coefficient of determination R^2 (how well the explanatory variables can explain the objective variable) of the prediction formula using Functional Independence Measure (FIM) at discharge as the objective variable was on average 0.65 (minimum 0.35 to maximum 0.82), whereas the R^2 of the prediction formula with FIM gain as the objective variable was on average as small as 0.22 (0.08 to 0.4).

Patients admitted to rehabilitation hospitals with an FIM score of 18 points were divided into patients whose discharge FIM score remained at 18 points (FIM gain of 0 points) and patients who acquired large FIM gains. In order to accurately predict this difference, the authors considered introducing a number of factors influencing FIM gain into the explanatory variables. In Meyer et al.'s review of 27 reports [1], 126 factors were inputted, of which 63 were significant explanatory variables. However, we cannot find any reports that use all of these 63 factors as explanatory variables. In fact, the number of significant factors incorporated into one prediction formula was on average only 4.1 (standard deviation 2.5) [1]. Furthermore, the Japanese Guidelines for the Management of Stroke 2015 state that "even if

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the variables used for prediction are simply increased, the prediction accuracy does not necessarily rise, indicating the advantages of using as simple prediction method as possible" [2].

If it is difficult or ineffective to create accurate prediction formulae by inputting a number of factors available at the time of admission into the explanatory variables, then by incorporating into the prediction formula "the amount of FIM improvement for one month since admission (FIM improvement for one month)," which is the result of many of these factors, it is possible to increase the prediction accuracy of FIM gain. Indeed, we are improving forecasts at the time of admission by using FIM improvement for one month.

In this study, we predicted FIM gain of stroke patients admitted to a *Kaifukuki* rehabilitation ward using multiple linear regression analysis. The aim of this study was to clarify how the prediction accuracy will increase by adding FIM improvement for one month to the explanatory variables rather than using a prediction formula that uses only data available at the time of admission as the explanatory variables.

Subjects and Methods

This research was a retrospective study. A total of 770 stroke patients who were admitted to the *Kaifukuki* rehabilitation ward in Hospital A between April 1, 2013 and June 17, 2016, after undergoing treatment at acute phase hospitals, were enrolled. The following patients were excluded: those with traumatic subarachnoid hemorrhage (3 cases), those aged younger than 40 years old (29 cases), those who died in the hospital (5 cases), those whose outcome was not recorded (7 cases), those admitted within 6 days or more than 60 days after onset (45 cases), those who spent less than 31 days in hospital (91 cases), those whose FIM score at admission or discharge was not recorded (2 cases), those whose FIM score at one month after admission was not recorded (17 cases), those who were readmitted (12 cases), those whose total score of the motor items of FIM (mFIM) at admission was 91 points (4 cases), and those whose FIM gain was less than 0 point (8 cases). The remaining 547 patients were included in this study.

A multiple regression analysis using mFIM gain as the objective variable was performed. The four items of age, number of days from onset to admission, admission mFIM, and the total score of the cognitive items of FIM (cFIM) at admission (model 1), or the six items of mFIM improvement for one month and cFIM improvement for one month, in addition to the preceding four items (model 2), were selected as explanatory variables. Regarding the two prediction equations obtained, the coefficient of determination adjusted for the degrees of freedom R^{*2} and the "residuals" obtained by subtracting the predicted value from the measured value of mFIM gain were investigated. Many reports have used the coefficient of determination R^2, yet by increasing the number of explanatory variables, even if doing so is not useful, R^2 will be a high value. Therefore, the value corrected by the number of explanatory variables and the amount of data so that the value decreases when a meaningless variable is used as an explanatory variable is R^{*2}, and there is the relationship $R^2 > R^{*2}$.

This study was approved by Hospital A's clinical research ethics committee. All personal information was converted to data so that individuals could not be identified. The FIM used was the Japanese version of the FIM, 3rd edition [3], and the statistical software used was IBM SPSS Statistics version 23.0.

Results

Table 1 shows the basic attributes of the 547 subjects. Other than a shorter period between onset and admission, the subjects were very similar to those recorded in the national survey of *Kaifukuki* rehabilitation wards in Japan [4]. The mFIM gain was in the range of 0 to 77 points, and the average was 21.2 ± standard deviation of 15.5 points.

R^{*2} was 0.364 in the prediction formula (model 1) when four items of the data at the time of admission were used as explanatory variables (Table 2a). R^{*2} was 0.711 in the prediction formula (model 2) when six items, where mFIM improvement for one month and cFIM improvement for one month were added to the preceding four items, were used as explanatory variables (Table 2b). In model 2, five explanatory variables excluding "number of days from onset to admission" were significant. The "standardized partial regression coefficient," which is the strength of the explanatory variables relative to the objective variable, were, from largest to smallest, mFIM improvement for one month, admission mFIM, admission cFIM, the patient's age, and cFIM improvement for one month. The "residual" obtained by subtracting the predicted value from the measured value of mFIM gain was 0 ± 12.3 for model 1 and 0 ± 8.3 for model 2.

As for the relationship between the measured value of mFIM gain and the residual, for model 1, the residual was negative (predicted value > measured value) for patients for whom the measured value of mFIM gain was 10 points or less, and the residual was often positive (measured value > predicted value) for patients for whom the measured value of mFIM gain was 50 points or more (Fig. 1a). In model 2, the absolute value of the residual decreased for patients for whom the measured value of mFIM gain was 10 points or less (Fig. 1b).

Discussion

This study demonstrates that, when predicting mFIM gain for stroke patients admitted to a *Kaifukuki* rehabilitation ward using multiple regression analysis, by adding FIM improvement for one month to the

Table 1. Clinical characteristics of subjects in this study.

	This study	National survey [4]
Number of patients	547	9,031
Age	69.8±12.1 (70)	73.3
Sex	Male 300, female 247	56.7%, 43.3%
Infarction, hemorrhage, SAH	318, 175, 54	—
Number of days from onset to admission	18.3±9.4 (16)	29.6±13.9
Number of days in hospital	91.3±39.1 (91)	81.3±45.1
Motor FIM score at admission	45.6±24.8 (46)	—
Cognitive FIM score at admission	22.1±9.3 (24)	—
Total FIM score at admission	67.7±32.3 (70)	71.1±31.3
Motor FIM improvement for one month	12.4±10.7 (11)	—
Cognitive FIM improvement for one month	2.4±3.5 (2)	—
Motor FIM score at discharge	66.8±24.4 (77)	—
Cognitive FIM score at discharge	26.4±8.4 (29)	—
Total FIM score at discharge	93.2±31.8 (107)	88.3±33.6
Motor FIM gain	21.2±15.5 (19)	—
Cognitive FIM gain	4.2±4.7(3)	—
Total FIM gain	25.4±18.3 (23)	17.1±17.4

FIM, Functional Independence Measure; SAH, Subarachnoid hemorrhage; —, not described.
Data for this study are expressed as number of patients or mean ± standard deviation (median value).

Table 2. Multiple linear regression analysis to predict motor FIM gain.

a) Model 1: Prediction formula with four explanatory variables available at admission.

	Coeff (*B*)	95% CI of B		Std Coeff (β)	Significance (*p*)
		Lower	Upper		
Age	−0.444	−0.534	−0.355	−0.348	<0.001
Number of days from onset to admission	−0.202	−0.316	−0.088	−0.123	0.001
Motor FIM at admission	−0.497	−0.559	−0.435	−0.798	<0.001
Cognitive FIM at admission	0.770	0.601	0.938	0.461	<0.001

Coeff, Coefficient; Std Coeff, Standard coefficient; CI, Confidence interval.
p Value, <0.001; Coefficient of determination (R^2), 0.368; Coefficient of determination adjusted for the degrees of freedom (R^{*2}), 0.364; Constant, 61.530.

b) Model 2: Prediction formula with six explanatory variables adding mFIM and cFIM improvements for one month to the four explanatory variables.

	Coeff (*B*)	95% CI of B		Std Coeff (β)	Significance (*p*)
		Lower	Upper		
Age	−0.238	−0.301	−0.175	−0.186	<0.001
Number of days from onset to admission	−0.060	−0.138	0.017	−0.036	0.128
Motor FIM at admission	−0.338	−0.384	−0.292	−0.543	<0.001
Cognitive FIM at admission	0.492	0.354	0.630	0.294	<0.001
Motor FIM improvement for one month	0.859	0.781	0.937	0.596	<0.001
Cognitive FIM improvement for one month	0.467	0.214	0.721	0.105	<0.001

p Value, <0.001; R^2, 0.715; R^{*2}, 0.711; Constant, 31.645.
There is no correlation between six explanatory variables of 0.8 or higher.

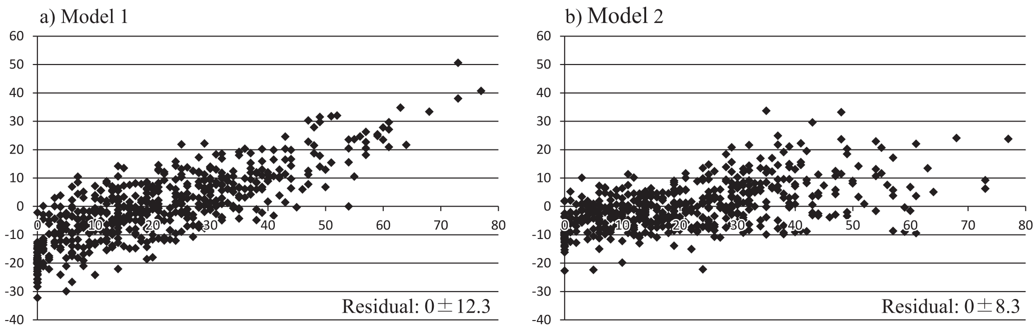

Figure 1. Relationship between the measured value of mFIM gain and the residual.
Model 1, Prediction formula with four explanatory variables available at admission.
Model 2, Prediction formula with six explanatory variables adding mFIM and cFIM improvements for one month to the four explanatory variables.
Horizontal axis, Measured value of mFIM gain; Vertical axis, Residual obtained by subtracting the predicted value from the measured value of mFIM gain; Dot, Each patient.

Table 3. Reports predicting FIM gain for stroke patients using multiple regression analyses.

Reports [Reference number]	FIM	Number of patients	Number of significant explanatory variables	R^2	R^{*2}
Nishioka et al. [5]	Total FIM	178	6	0.426	—
Tokunaga et al. [6]	Motor FIM	1,884	7	0.421	—
Tokunaga et al. [7]	Motor FIM	2,542	6	—	0.405
Scrutinio et al. [8]	Total FIM	722	5	0.275	—
Tokunaga et al. [9]	Total FIM	256	3	0.275	—
This study	Motor FIM	547	5	0.715	0.711

R^2, Coefficient of determination; R^{*2}, Coefficient of determination adjusted for the degrees of freedom.

explanatory variables, the coefficient of determination adjusted for the degrees of freedom R^{*2} of the prediction formula improved from 0.364 to 0.711. In particular, the prediction accuracy was improved for patients with an mFIM gain of 10 points or less. In the reports [5−9] predicting FIM gain using multiple regression analysis for stroke patients admitted to convalescent rehabilitation hospitals, there was no prediction formula adding FIM improvement for one month to the explanatory variables, such as that used in this study (Table 3).

The Japanese Guidelines for the Management of Stroke 2015 [2] note that "simply increasing the variables used for prediction does not necessarily improve prediction accuracy [10, 11], demonstrating an advantage of using the simplest prediction method [12]." On the other hand, there are reports that adding items such as co-morbidity [13], Stroke Impairment Assessment Set (SIAS) [14], and *Nichijo-seikatsu-kino-hyokahyo* (NSKH) [9] to the explanatory variables can raise the prediction accuracy of multiple regression analyses. Of course, research on improving prediction accuracy by incorporating an appropriate number of factors that have a large influence on mFIM gain into the prediction formula is also necessary.

Let us consider the magnitude of R^{*2} in the prediction of mFIM gain (improved from 0.364 to 0.711). In Meyer et al.'s review of stroke patients admitted to "acute-phase hospitals," R^2 for predicting FIM gain was as low as 0.08 to 0.4 (with an average of 0.22) [1]. R^2 was also in the range of approximately 0.275 to 0.426 in the case of stroke patients who were admitted to "convalescent rehabilitation hospitals" [5−9] (Table 3). There is no clear criterion regarding how much higher R^2 should be, but it is said that $R^2 \geq 0.5$ (desirably $R^2 \geq 0.7$) [15]. Of the reports so far, the numerical value of R^{*2} of 0.711 in multiple regression analyses for predicting FIM gain was the largest, and attained the desirable R^2. The R^{*2} increase of discharge FIM due to the addition of co-morbidity was 0.066 (from 0.732 to 0.798) [13], the R^{*2} increase of discharge FIM due to the addition of SIAS was 0.03 (from 0.61 to 0.64) [14], and the R^2 increase of FIM gain due to the addition of NSKH was 0.036 (from 0.239 to 0.275) [9]. Compared to these, the R^{*2} increase of FIM gain of 0.347 (improved from 0.364 to 0.711) was large. In addition, when performing an analysis using discharge mFIM as the objective variable, R^{*2} of model 1 was 0.744, and R^{*2} of model 2 was 0.884 (data not shown).

The limitations of this study are as follows. (1) Whether the four explanatory variables are appropriate. In the review of 16 reports that predicted discharge FIM or FIM gain in stroke patients admitted to *Kaifukuki* rehabilitation wards in Japan using multiple regression analysis, factors that were used in more than five reports and were significant in more than half of them were age, number of days from onset to admission, admission mFIM, admission cFIM, total FIM score at admission, and number of days in hospital [16]. Therefore, in this study, four items excluding total FIM score at admission and number of days in hospital were used as explanatory variables. (2) There is an opinion that the prediction of mFIM gain should use only data available at the time of admission. Although this is ideal, the prediction accuracy of the current multiple regression analysis is considered to be at “a level that can predict group trends, but is not so high as to predict individual cases” [17] even when predicting discharge FIM. In order to improve the prediction accuracy of mFIM gain, it is also necessary to consider methods of adding FIM improvement for one month to the explanatory variables. (3) Since the numerical value of R^2 (or R^{*2}) differs depending on the target patients, it is difficult to accurately compare this numerical value among reports of different target patients. (4) The survey was conducted in one hospital. (5) Its validity was not verified.

It may be possible to increase the prediction accuracy to the level where prediction in individual cases is accurate, by combining the addition of FIM improvement for one month to the explanatory variables (shown to be useful in this study), the addition of appropriate factors to explanatory variables, and stratifications of admission mFIM [7, 18, 19]. However, this subject is left for future research. Furthermore, it may be desirable to conduct a survey at an even earlier time than one month (such as FIM improvement for one week). The authors are conducting family interviews one month after admission, and the prognosis prediction at the time of admission is revised using FIM improvement for one month. The prediction accuracy should increase as the timing of this survey approaches the discharge time (the median length of hospitalization was 91 days). In the future, it will be necessary to clarify how accurate the predictions can be made when FIM improvement is evaluated much earlier than one month from admission.

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