Formula for Predicting FIM Gain and Discharge FIM —Methods using Median Values of FIM Gain Stratified by Admission FIM, Age, Cognitive Function, and Transfer Interval—

Makoto Tokunaga, MD, PhD,1 Katsuhiko Sannomiya. RPT,1 Yukihiko Nakashima, OTR,1 Shinichi Nojiri, RPT,1 Kaori Tokisato, MD,1 Kenichi Katsura, MD,1 Susumu Watanabe, MD, PhD,1 Ryoji Nakanishi, MD, PhD,1 Hiroaki Yamanaga, MD, PhD1

1Department of Rehabilitation, Kumamoto Kinoh Hospital, Kumamoto, Japan

ABSTRACT

Objective: To predict FIM gain and discharge FIM score by multiplying the standard value by influence coefficients for age, cognitive function, and transfer interval.

Methods: The subjects were 1,118 stroke patients admitted to a Kaifukuki rehabilitation ward of hospital A. The median value of motor FIM (mFIM) gain and discharge mFIM based on mFIM at the time of admission was used as the standard value. We then created a formula for predicting mFIM gain and discharge mFIM by multiplying the standard value by the influence coefficients for age, cognitive function, and transfer interval.

Results: The correlation coefficient between the actual and predicted values was 0.681 in the prediction of mFIM gain and 0.874 in the prediction of discharge mFIM. The residual of the subtraction of the predicted value from the actual value was 1.4±12.5 (median value: 0) in the prediction of mFIM gain, and 1.3±12.6 (median value: 0) in the prediction of discharge mFIM.

Conclusion: The correlation coefficient is comparable with those of reports that use multiple regression analysis. This new method clearly showed the relationship between factors and mFIM gain/discharge mFIM.

Key words: Functional Independence Measure, FIM gain, multiple regression analysis, formula, factors

Introduction

Multiple regression analysis is often used to analyze the outcome of stroke patients influenced by multiple factors. Regarding reports from Kaifukuki rehabilitation wards in Japan, there are 14 reports [2–15] that use a multiple regression analysis with Functional Independence Measure (FIM) [1] gain (discharge FIM − admission FIM) or discharge FIM as the objective variable.

The prediction formula for a multiple regression analysis is $y = aX_1 + bX_2 + cX_3$ ($y$: objective variable, $X_1$, $X_2$, $X_3$: explanatory variables, a–c: regression coefficients). This supposes that there is a linear relationship between the explanatory variables and the objective variable and adds the influence of the various factors together. However, there is not necessarily a linear relationship between the explanatory variables and the objective variable and adds the influence of the various factors together. For example, the relationship between admission FIM and FIM gain is not linear, but inverted V-shaped. FIM gain is smaller in the total assistance level because it includes numerous patients who have difficulty in recovering, and gains decrease due to the ceiling effect in the minimal assistance level [16]. Compared to this, there are numerous moderate-assistance patients with large gains [16]. It has been reported that FIM improvement decreases almost linearly in stroke patients after the age of 70, but remains constant for patients 69 and younger. In addition, it may be more suitable not to add the influence of each factor, but rather to perform multiplication by the influence coefficients after stratifying the influence of each factor.

Thus, we obtained the median (standard value) of
the admission FIM-based FIM gain. We consider a new method in which the standard value is multiplied by the coefficient of the influence of age in order to obtain the predicted value of FIM gain that takes into consideration admission FIM and age.

The aim of this study is to create a formula for predicting FIM gain and discharge FIM by multiplying the medians of admission FIM-based FIM gain and discharge FIM (standard value) by the influence coefficients for age, cognitive function, and transfer interval.

**Subjects and Methods**

A total of 1,118 stroke patients who were admitted to the Kaijukuki rehabilitation ward in Hospital A between April 1, 2008 and July 16, 2013, after undergoing treatment at acute hospitals, were enrolled. The following patients were excluded: those with subarachnoid hemorrhage, those admitted within 7 days or more than 60 days after onset, those who spent less than 14 days or over 180 days in hospital, those who died in hospital, and those with motor FIM score on admission of 91 points. Table 1 shows the basic attributes of the 1,118 subjects. Other than a shorter period between onset and admission, the subjects were very similar to those recorded in the national survey of Kaijukuki rehabilitation wards [19].

**Study 1: Standard Values of Admission mFIM-based FIM Gain and Discharge mFIM**

The motor items of FIM at admission (admission mFIM) were split into 13 groups in 6-point increments (13–18, 19–24, 25–30, 31–36, 37–42, 43–48, 49–54, 55–60, 61–66, 67–72, 73–78, 79–84, and 85–90 points). We obtained the median for mFIM gain in each group and used that as the “standard value” for mFIM gain. The standard value of discharge mFIM was set as the sum of admission mFIM and the standard value of mFIM gain. Spearman’s rank correlation coefficient (significance level below 5%) was used to test whether there was a correlation between the actual and standard values. In addition, we calculated the “residual” of the actual value by subtracting the standard value from it. We used the median value instead of the mean value because it is more difficult for the median value to be influenced by outliers.

**Study 2: Correcting the Standard Value for Age**

For all patients, the numerical value (P) was obtained by dividing the “actual value of mFIM gain” by the “standard value of mFIM gain.” Similarly, the numerical value (Q) was obtained by dividing the “actual value of discharge mFIM” by the “standard value of discharge mFIM.” The ages were split into seven groups: 59 and below, 60–69, 70–74, 75–79, 80–84, 85–89, and 90 and above. We obtained the median values of P and Q in each of the age groups and set them as the “influence coefficient for age.” We multiplied the standard value of mFIM gain obtained in Study 1 by the “influence coefficient for age” and set it as the “predicted value of mFIM gain for which the standard value was corrected for age.” Similarly, we multiplied the standard value of discharge mFIM by the “age influence coefficient” and set it as the “predicted value of discharge mFIM for which the standard value was corrected for age.”

**Study 3: Correcting for Cognitive FIM**

We further corrected the standard value that had been corrected for age, for cognitive FIM. The
admission cognitive FIM was split into six groups: 5–9, 10–14, 15–19, 20–24, 25–29, and 30–35 points. The actual value/predicted value was taken to be the “influence coefficient for cognitive function.” The “predicted value of mFIM gain/discharge mFIM for which the standard value was corrected for age and cognitive function” was obtained using the same method as in Study 2.

Study 4: Correcting for Number of Days between Onset and Hospital Admission

We further corrected the standard value that had been corrected by age and admission cognitive FIM by the number of days between onset and hospital admission. The number of days between onset and admission was split into seven groups: 13 days and below, 14–20, 21–27, 28–34, 35–41, 42–48, and 49 and above. The actual value/predicted value was taken to be the “influence coefficient for transfer interval.” The “predicted value of motor FIM gain/discharge motor FIM for which the standard value was corrected for age, cognitive function, and transfer interval” was obtained using the same method as in Study 2. The correlation between the predicted and actual values as well as the residual of the actual value from which the predicted value was subtracted were calculated.

Results

In cases where the admission mFIM scores were between 13–18, 19–24, 25–30, 31–36, 37–42, 43–48, 49–54, 55–60, 61–66, 67–72, 73–78, 79–84, and 85–90 points, the median values of mFIM gain were 12, 23, 34, 35, 33, 29, 27, 22, 20.5, 15, 10, 7, and 2 points, respectively, and these values were taken to be the standard values for mFIM gain (Figure 1). There was a significant positive correlation between the standard values for mFIM gain and the actual mFIM gain (correlation coefficient 0.618, \( p < 0.001 \)) (Table 2a). The mean±standard deviation of the residual, which was obtained by subtracting the standard value of mFIM gain from the actual value of mFIM gain, was 0.3±12.8 (mean value: 0). There was a significant positive correlation between the standard values of the discharge mFIM and the actual values of the discharge mFIM (correlation coefficient 0.861, \( p < 0.001 \)). The residual of the actual value of discharge mFIM, which was obtained by subtracting the standard value of discharge mFIM from it, was 0.3±12.8 (mean value 0) points (Table 2a).

The influence coefficient for age in Study 2 (actual value/standard value) in the mFIM gain was high in young patients (the actual values were higher than the standard values in young patients) and low in older patients (the actual values were lower than the standard values in older patients) (Figure 2a). There was a similar trend also in the discharge mFIM; however, the influence of the difference in age was small (Figure 2b).

The influence coefficient for cognitive function (actual value/predicted value) in Study 3 was 0.386 for admission cognitive FIM scores between 5–9 points (the actual values are lower than the predicted values by the admission mFIM and age when the cognitive FIM is low) and 0.954 for admission cognitive FIM scores between 10–14 points, and was about 1.0 in the

Figure 1. Relationship between motor FIM at admission and motor FIM gain.
Numerical value, median value.

Figure 2. Influence coefficient for age.
Numerical value, median value.
Standard value, the median of FIM gain in 13 groups stratified by motor FIM at admission as shown in Figure 1 (Study 1).

four groups with admission cognitive FIM scores between 15–35 points (Figure 3a). There was a similar trend also in discharge mFIM; however, the influence of the difference in cognitive FIM was small (Figure 3b).

In the influence coefficient for transfer interval in Study 4, mFIM gain decreased as the number of days between onset and admission increased (Figure 4a). There was a similar trend also in discharge mFIM; however, the influence of the difference in transfer interval was small (Figure 4b).

The predicted value of the mFIM gain score is $34 \times 0.647 \times 0.954 \times 0.922 = 19.3$, if for example, the admission mFIM score is 28, the age is 87, the admission cognitive FIM score is 12, and the number of days between onset and admission is 40. The correlation between the predicted value and actual value was $0.681 (p<0.001)$ in mFIM gain and $0.874 (p<0.001)$ in discharge mFIM (Table 2d). The residual was $1.4\pm12.5$ (median value: 0) in mFIM gain and $1.3\pm12.6$ (median value: 0) in discharge mFIM (Table 2d).

**Discussion**

In the present study, we predicted mFIM gain and discharge mFIM by multiplying the median value (standard value) of admission mFIM-based mFIM gain and discharge mFIM by the influence coefficients for age, cognitive function, and transfer interval. The correlation coefficient between the actual and predicted values was $0.681$ in the prediction of mFIM gain and $0.874$ in the prediction of discharge mFIM.

The correlation of the median value (standard value) of the admission mFIM-based discharge mFIM in Study 1 was $0.861$ and the residual was $0.3\pm12.8$ (Table 2a). We expected the correlation coefficient between the actual and predicted values of the
Tokunaga M et al: Formula for predicting FIM gain and discharge FIM

10
discharge mFIM to increase and the standard deviation of the residual to decrease by the multiplication by the influence coefficients for age, cognitive function, and transfer interval in Studies 2–4. The “actual value/predicted value” differs when stratified by age (Figure 2b), cognitive function (Figure 3b), or transfer interval (Figure 4b) and it was considered meaningful to correct their influence. However, the results showed that the correlation coefficient between the actual and predicted values of discharge mFIM was only raised by 0.013 (from 0.861 to 0.874) and the standard deviation of the residual was only lowered by 0.2 (from 12.8 to 12.6) (Tables 2a, 2d) even after the multiplication by the influence coefficients for these three factors. However, the effect of correcting the three factors was large in cases where the mFIM gain was predicted, and the correlation coefficient between the actual and predicted values was raised by 0.063 (from 0.618 to 0.681) and the standard deviation of the residual was lowered by 0.3 (from 12.8 to 12.5) (Tables 2a, 2d) when multiplied by the influence coefficients for these factors.

Multiple regression analyses that use discharge FIM as the objective variable have been reported in 10 articles from rehabilitation hospitals in Japan [2–11]; however, Jeong et al. [2] and Sonoda et al. [3] are the only two reports that recorded a correlation coefficient between the actual and predicted values.

Jeong et al. selected 941 stroke patients from Kafukuki rehabilitation wards recorded in the Japan Rehabilitation Database as subjects, conducted a variable selection multiple regression analysis that used the total discharge FIM score as the objective variable, and selected seven of ten explanatory variables: admission mFIM, admission cognitive FIM, age, admission Glasgow coma scale (GCS) score, number of days from onset to admission, modified Rankin scale (mRS) score before onset, and presence of complications, and reported that the adjusted coefficient of determination ($R^2$) was 0.66. A high correlation between the predicted value of discharge FIM and the actual value was found (0.84) [2] when

Figure 3. Influence coefficient for cognitive function.
Numerical value, median value.
Predicted value, the predicted value of motor FIM gain for which the standard value was corrected for age and cognitive function, using the method in Study 2.

Figure 4. Influence coefficient for transfer interval.
Numerical value, median value.
Predicted value, the predicted value of motor FIM gain for which the standard value was corrected for age, cognitive function, and transfer interval, using the method in Study 3.

the data for 999 subjects from the verification group was input into the prediction formula. Although there are differences between this study and their report, such as the fact that the results in this report are from a single institution, using the mFIM score and not the total FIM score, a prediction formula with only the four variables of admission mFIM, age, admission cognitive FIM, and transfer interval, and not establishing a verification group, our correlation coefficient of this study (0.874) is smaller than that reported by Sonoda et al. [3] (0.88 in the ordinary prediction and 0.89–0.93 in the reciprocal prediction).

The prediction of the discharge FIM through the methods in this report has the same level of accuracy when compared to the two multiple regression analysis reports [2, 3] above that recorded the correlation coefficient between the actual and predicted values.

The residual, which was calculated by subtracting the predicted value from the actual value, was not recorded in Jeong et al. [2]; however, in Sonoda et al. [3], the residual was 8.06±6.29 (median value: 6.26) in cases where admission mFIM was used as an explanatory variable, and 6.19±5.04 (median value: 4.57) in cases where admission mFIM was input in multiple regression analysis. This study (new method) does not use a multiple regression analysis; however, it is recorded in the table for comparison purposes.

The data of residual is expressed as mean±standard deviation (median); reciprocal, reciprocal of admission mFIM was input in multiple regression analysis.

Table 3. Multiple regression analysis to predict FIM at discharge or FIM gain.

<table>
<thead>
<tr>
<th>Objective variable</th>
<th>Report</th>
<th>Correlation</th>
<th>Residual</th>
<th>R²</th>
<th>Number of patients</th>
<th>Number of institutions</th>
<th>FIM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jeong et al. [2]</td>
<td>0.84</td>
<td>–</td>
<td>0.66</td>
<td>941</td>
<td>multiple</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Sonoda et al. [3]</td>
<td>0.89–0.93 (reciprocal)</td>
<td>6.19±5.04 (4.57)</td>
<td>–</td>
<td>87</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Liu et al. [4]</td>
<td>–</td>
<td>–</td>
<td>0.798</td>
<td>106</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Iwai et al. [5]</td>
<td>–</td>
<td>–</td>
<td>0.719</td>
<td>482</td>
<td>multiple</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Tokunaga et al. [6]</td>
<td>–</td>
<td>–</td>
<td>0.710</td>
<td>256</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Jeong et al. [7]</td>
<td>–</td>
<td>–0.28±12.88</td>
<td>0.649</td>
<td>680</td>
<td>multiple</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Tsuji et al. [8]</td>
<td>–</td>
<td>–</td>
<td>0.64</td>
<td>190</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Inouye [9]</td>
<td>–</td>
<td>–</td>
<td>0.57 (over 80 years old), 0.64 (mild)</td>
<td>464</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Hirano et al. [10]</td>
<td>–</td>
<td>–</td>
<td>0.5 (severe), 0.51 (moderate), 0.64 (mild)</td>
<td>482</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Mutai et al. [11]</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>174</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>This study (new method)</td>
<td>0.874</td>
<td>1.3±12.6 (0)</td>
<td>–</td>
<td>1,118</td>
<td>one</td>
<td>motor FIM</td>
</tr>
<tr>
<td>FIM at discharge</td>
<td>Tokunaga et al. [3]</td>
<td>–</td>
<td>–</td>
<td>0.413 (severe), 0.723 (mild)</td>
<td>256</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Imada et al. [12]</td>
<td>–</td>
<td>–</td>
<td>0.377 (severe), 0.693 (mild)</td>
<td>1,137</td>
<td>one</td>
<td>motor FIM</td>
</tr>
<tr>
<td></td>
<td>Tokunaga et al. [13]</td>
<td>–</td>
<td>–</td>
<td>0.32 (severe), 0.51 (mild)</td>
<td>306</td>
<td>multiple</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Shirashi et al. [14]</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
<td>68</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>Shirashi et al. [15]</td>
<td>–</td>
<td>–</td>
<td>0.49</td>
<td>81</td>
<td>one</td>
<td>total FIM</td>
</tr>
<tr>
<td></td>
<td>This study (new method)</td>
<td>0.681</td>
<td>1.4±12.5 (0)</td>
<td>–</td>
<td>1,118</td>
<td>one</td>
<td>motor FIM</td>
</tr>
</tbody>
</table>

Correlation, correlation between actual value and predicted value; residual, actual value–predicted value; R², coefficient of determination; FIM, Functional Independence Measure.

severe, severe patients; moderate, moderate patients; mild, mild patients.

Value of residual is expressed as mean/standard deviation (median); reciprocal, reciprocal of motor FIM at admission was input in multiple regression analysis.

This study (new method) does not use a multiple regression analysis; however, it is recorded in the table for comparison purposes.
in the minimal-assistance level). The difference between the 13-point and 14-point score in admission FIM is 0.055 (difference between 1/13 and 1/14) if they are inverted and the difference between the 80-point and 81-point score in admission mFIM is 0.00015 (difference between 1/80 and 1/81) if they are inverted [3]. They were able to raise the precision of the prediction formula by reducing the influence of those patients with high admission mFIM scores (patients with a ceiling effect) on discharge mFIM by means of this operation. The method of the present study was able to correct not only the ceiling effect, but also the small mFIM gain in patients who had low admission mFIM. This led to the result that the median of residuals which were obtained by subtracting the predicted value from the actual value was 0.055 (difference between 13-point and 14-point score in admission FIM) (Table 3).

In this study, the reason why the correlation between the predicted and actual values remained at 0.874 is considered to be that the influence of the pre-onset mRS and complications, as well as the influence of the number of training units and number of days in hospital as used in Jeong et al. [2], were not corrected. However, Sonoda et al. [3], which had high correlation coefficients (0.89–0.93), used the same four explanatory variables as in the present study; thus, we cannot say that having four explanatory variables was the major cause of this correlation value.

If the regression coefficient of age is −0.34 [2] in a multiple regression analysis, this implies that the discharge FIM lowers by 0.34 for every year that a person ages. In other words, we assume that there is a line-shaped relationship (linear relationship) between the objective variable and the explanatory variables. However, the influence of age on FIM gain and discharge FIM changes based on admission FIM increases has not been shown to hold true for all ages [17, 18].

Since there is a correlation between the admission mFIM and the discharge mFIM in the first place, it was expected that the correlation coefficient that predicts discharge mFIM from admission mFIM would be larger than the correlation coefficient that predicts FIM gain from admission mFIM (Table 2). In previous studies as well, \( R^2 \) in the multiple regression analyses that used FIM gain as the objective variable [6, 12–14] was smaller than \( R^2 \) in those that used discharge FIM as the objective variable [2, 4–10] (Table 3).

Advantages of multiple regression analysis are that it can analyze multiple factors simultaneously, that weighting of factors is shown as a numerical value of a standardized partial regression coefficient, that it can yield immediate results if using statistical software, and that it is an established method. Disadvantages of multiple regression analysis are that the prediction formula becomes unstable in cases where there is a strong correlation between factors (multicollinearity), that it assumes a linear relationship between the objective variable and the explanatory variables, and that it is difficult to visually comprehend results.

Advantages of the new method in this study are that a linear relationship between factors (explanatory variables) and objective variable is not required, and that it is possible to visually comprehend the relationship between factors and objective variable. Disadvantages of this method are that time and effort are required in order to produce results, that it is not an established method, that it is necessary to examine the influence of each factor individually, and that it cannot analyze multiple factors simultaneously.

This study has the following limitations. First, if a “standard value” is obtained using young patients with normal cognitive function and fast transfer intervals as subjects, the influence of age, cognitive function, and transfer interval can be shown as influence coefficients between 0–1. However, this method could not be carried out as the number of patients became too small. Second, the results are from one institution and the external validity has not been proven.

Despite these limitations, the new method described in this study for predicting FIM gain and discharge FIM by multiplying the median value (standard value) of admission FIM-based FIM gain by the influence coefficients for age, cognitive function, and transfer interval has the same degree of accuracy as multiple regression analysis and also is useful because it can clearly show the relationship between factors and FIM gain/discharge FIM.

References