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*Original Article*

# Three different methods for demonstrating that gain in Functional Independence Measure increases with higher cognitive ability

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**ABSTRACT**
Tokunaga M, Sannomiya K, Ohashi T, Yonemura M, Sakata D, Imaya M, Sugitani E, Mitsunaga W, Shiiba S, Nakashima Y. Three different methods for demonstrating that gain in Functional Independence Measure increases with higher cognitive ability. Jpn J Compr Rehabil Sci 2014; 5: 26−32.
**Objective:** To use three different methods to elucidate the association between the degree of improvement in the motor items of the Functional Independence Measure (motor FIM gain) and cognitive ability.
**Methods:** The subjects were 1,101 cerebral stroke patients admitted to Kaifukuki rehabilitation wards. Three different methods were used to investigate the association between total score on FIM cognitive items on admission (cognitive FIM on admission) and motor FIM gain: (1) multiple regression analysis with motor FIM effectiveness as the target variable, (2) multiple regression analysis with motor FIM on admission restricted to narrow bands, and (3) adjustment using a standard severity distribution.
**Results:** In multiple regression analysis used in methods (1) and (2), cognitive FIM on admission was selected as an explanatory variable, with a positive coefficient of regression. In method (3), mean adjusted motor FIM gain for dementia patients was lower than mean motor FIM gain for non-dementia patients.
**Conclusion:** All three methods were capable of showing that FIM gain increases with higher cognitive function.

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**Key words:** FIM effectiveness, multiple regression analysis, FIM gain, stratification

## Introduction

The Functional Independence Measure (FIM) is a technique used for evaluating activities of daily living (ADL), with a total score of 13−91 points on 13 motor items (motor FIM) and of 5−35 points on 5 cognitive items (cognitive FIM) indicating that an individual is capable of independent ADL. FIM gain (FIM on discharge − FIM on admission) represents the improvement in FIM during hospitalization, and FIM efficiency is the level of improvement in FIM per day, calculated as FIM gain divided by number of days in hospital.

FIM gain is low both for patients who require complete assistance, who are unlikely to improve, and for those who require only light assistance because of the ceiling effect. Compared with these, patients who require moderate assistance exhibit a larger gain. The fact that FIM gain is affected by FIM on admission due to poor improvement by severe patients and the ceiling effect is a major impediment to any investigation of the effect of cognitive ability on FIM gain. In multiple regression analysis using factors such as age, motor FIM on admission, and cognitive FIM on admission as explanatory variables and motor FIM gain as the target variable, for example, the regression coefficients for cognitive and motor FIM on admission are both negative (motor FIM gain decreases with higher FIM on admission) [1]. Only after stratification or correction of FIM gain can motor FIM gain be shown to increase with higher cognitive FIM on admission.

One technique that is frequently used to resolve the problem that FIM gain is affected by FIM on admission (FIM gain is an index dependent on FIM on admission) is motor FIM effectiveness (1), calculated as motor

FIM gain/(91 − motor FIM on admission) [2]. In patients with motor FIM on admission of 81 points, for example, the maximum potential motor FIM gain is 10 points (91 points − 81 points), and motor FIM effectiveness represents the proportion of actual improvement as a value between 0 and 1. Imada *et al.* [3] used multiple regression analysis for severe patients not affected by the ceiling effect (motor FIM on admission of 13−34 points) (2) to show that motor FIM gain increases with higher cognitive FIM on admission. Other previously unreported but conceivable methods for overcoming the problem that FIM gain is affected by FIM on admission are to perform multiple regression analysis while restricting motor FIM on admission to narrow bands (eliminating differences in motor FIM on admission within the same group) (3), or to regard the distribution of severity among non-dementia patients as the "standard severity distribution," and calculate adjusted motor FIM gain on the assumption that the age and severity distributions of dementia patients admitted to hospital follow the same standard severity distribution (4).

The objective of this study was to investigate whether the three different methods (1), (3), and (4) above, can be used to show that motor FIM gain increases with higher cognitive FIM on admission.

## Subjects and Methods

This was a retrospective epidemiological study. The subjects were 1,101 cerebral stroke patients who had been admitted to Kaifukuki rehabilitation wards in K Hospital between April 1, 2008, and July 16, 2013, after undergoing treatment at an acute hospital, excluding 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, those with motor FIM on admission of 91 points, and those with motor FIM gain less than 0 points.

All the required items were input for all subjects, with no missing values. Table 1 shows the basic attributes of the 1,101 subjects. Other than exhibiting a shorter period between onset and admission, the subjects were very similar to those recorded in the national survey of Kaifukuki rehabilitation wards [4].

This study was based on the regulations of the Clinical Research Ethics Committee of the authors' hospital, and was performed with the permission of staff previously designated by the Clinical Research Ethics Committee. All personal information was converted to data, which was handled in such a way that individuals could not be identified.

*Study 1: FIM effectiveness*

The value of motor FIM effectiveness, calculated as (motor FIM on discharge − motor FIM on admission)/(91 − motor FIM on admission), was calculated for each patient. A motor FIM score on admission of 91 meant that the denominator was 0, and a FIM gain of less than 0 meant that the value of FIM effectiveness was negative, and patients with these scores were therefore excluded. The association between motor FIM on admission and FIM effectiveness was investigated by dividing patients into 13 groups according to FIM score on admission in 6-point increments (13−18 points, 19−24 points, … 85−90

**Table 1.** Clinical characteristics of subjects in this study compared with national survey.

| | This study | National survey [4] |
|---|---|---|
| Number of patients | 1,101 | 14,011 |
| Sex | Male 670, female 431 | 56.8% males, 43.2% females |
| Infarction, hemorrhage | Infarction 706, hemorrhage 395 | – |
| Age | 68.9±13.7 | 72 |
| Duration from onset to admission | 21.1±10.4 | 36.6 |
| Duration of hospitalization | 81.4±39.9 | 89.4 |
| Motor FIM on admission | 48.8±25.6 | – |
| Cognitive FIM on admission | 22.8±9.4 | – |
| Total FIM on admission | 71.6±33.0 | 68.4 |
| Motor FIM on discharge | 67.9±24.2 | – |
| Cognitive FIM on discharge | 26.5±8.4 | – |
| Total FIM on discharge | 94.4±31.4 | 85.8 |
| Motor FIM gain | 19.1±15.26 | – |
| Cognitive FIM gain | 3.7±4.5 | – |
| Total FIM gain | 22.8±17.9 | 17.4 |

FIM, Functional Independence Measure.
Data for this study are expressed as mean ± standard deviation, or number of patients.

points), and calculating the mean FIM effectiveness of each of these groups. Multivariate analysis for selected variables was then performed, with the five items of age, duration from onset to admission, duration of hospitalization, motor FIM on admission, and cognitive FIM on admission as explanatory variables (selected as explanatory variables with *F*-statistic ≥2), and motor FIM effectiveness as the target variable.

*Study 2: Multivariate analysis with motor FIM on admission restricted to narrow bands*

Imada *et al.*'s subjects (severe patients with motor FIM on admission of 13–34 points) [3] were excluded from the analysis, and the remaining 719 patients (with motor FIM on admission of 35–90 points) were divided into seven groups in 8-point increments (35–42 points, 43–50 points, … 83–90 points), and multivariate analysis was performed with the same selected variables as in Study 1. The aim of restricting motor FIM on admission to narrow bands was to eliminate differences in motor FIM on admission within the same group. If this method were successful, motor FIM on admission should not be selected as the explanatory variables and cognitive FIM on admission should result in a positive coefficient of regression.

*Study 3: Correction by standard severity distribution*

Patients were stratified into a total of six groups, two according to age (≤74 and ≥75 years old) and three by motor FIM on admission in 26-point increments (13−38 points, 39−64 points, and 65−90 points). Patients were categorized as not having dementia if their cognitive FIM on admission was 25 points or more (mean score of 5 points for each cognitive item, i.e. the standard level for supervision; 566 patients), and as having dementia if their score was 24 points or less (535 patients). The patient distribution of non-dementia patients in the six groups stratified by age and motor FIM on admission was regarded as the "standard severity distribution." For patients with dementia, the mean ages, motor FIM on admission, and motor FIM gain were calculated for each of these six groups divided by age and motor FIM on admission. The standard severity distribution was applied to these, and the adjusted ages, adjusted motor FIM on admission, and adjusted motor FIM gain were calculated.

## Results

Figure 1a shows the association between motor FIM on admission and FIM effectiveness. When patients were divided into 13 groups by motor FIM on admission in 6-point increments, FIM effectiveness increased with higher FIM on admission when FIM on admission was within the range of 13−54 points

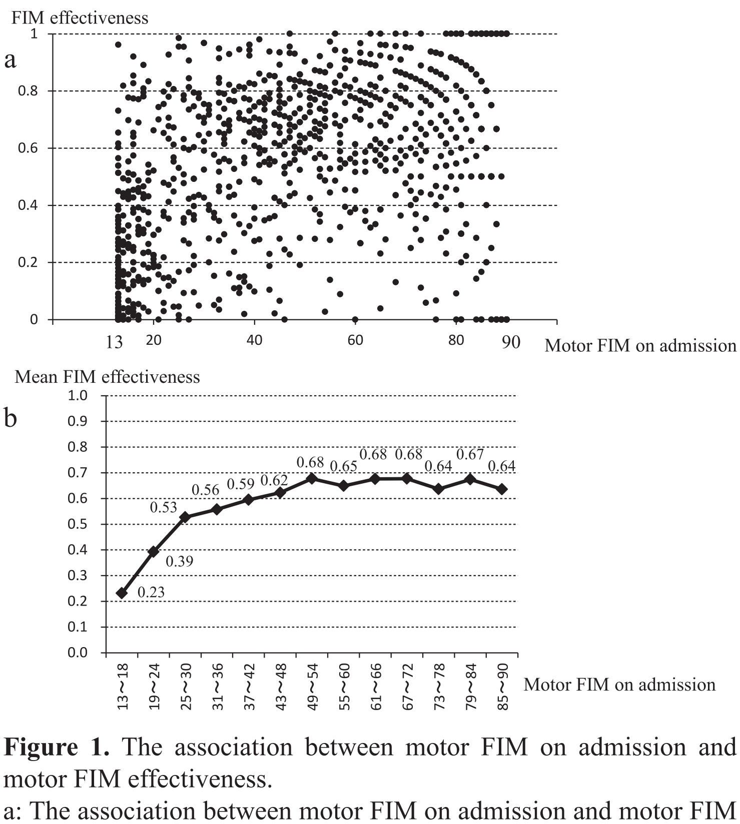


**Figure 1.** The association between motor FIM on admission and motor FIM effectiveness.
a: The association between motor FIM on admission and motor FIM effectiveness in each patient (●).
b: Mean motor FIM effectiveness when patients were divided into 13 groups by motor FIM on admission in 6-point increments.

(Figure 1b).

Multivariate regression analysis of selected variables with FIM effectiveness as the target variable (Table 2) selected all five items of age, duration from onset to admission, duration of hospitalization, motor FIM on admission, and cognitive FIM on admission as explanatory variables. The coefficient of regression was positive for the duration of hospitalization, motor FIM on admission, and cognitive FIM on admission (motor FIM gain increased as these values increased), and negative for age and duration from onset to admission (motor FIM gain decreased as these values increased). The adjusted coefficient of determination $R^2$ (the proportion explaining the regression equation) was 0.419.

In multivariate regression analysis with motor FIM on admission restricted to narrow bands (Table 3), motor FIM on admission was not selected as an explanatory variable for motor FIM scores on admission in the range of 35−50 points. However, motor FIM on admission was selected as an explanatory variable for motor FIM scores on admission in the range of 51−90 points, with a negative coefficient of regression due to the ceiling effect. For motor FIM on admission in the ranges of 35−50 points and 67−82 points, cognitive FIM on admission was selected as an explanatory variable, with a positive coefficient of regression.

Correction using the standard severity distribution (Table 4) involved a correction of the mean age difference between patients with and without dementia of 4.1 years (71.0−66.9 years) to 0.1 years (67.0−66.9 years). The difference in mean motor FIM on admission was corrected from 31.4 points (64.0 − 32.6 points) to 4.2 points (64.0 − 59.8 points). Adjusted mean motor FIM gain was lower for dementia patients (16.5 points) than for non-dementia patients (17.6 points).

## Discussion

Koh *et al*. [5] reviewed factors affecting the outcomes of rehabilitation, and found that few studies have shown that cognitive ability affects FIM gain or FIM efficiency in patients with stroke [6−9]. The reasons for this include the correlation between motor FIM and cognitive FIM, the presence of confounding factors, little improvement in severe patients, and the ceiling effect, and if these are not corrected appropriately then it may not be possible to reach any

**Table 2.** Multivariate analysis with motor FIM effectiveness as the target variable.

| Target variable | Motor FIM effectiveness | |
|---|---|---|
| Number of patients | 1,101 | |
| | Coefficient of regression | *F*-statistic |
| Age | −0.005 | 91.7 |
| Duration from onset to admission | −0.004 | 31.4 |
| Duration of hospitalization | 0.002 | 75.5 |
| Motor FIM on admission | 0.004 | 58.2 |
| Cognitive FIM on admission | 0.011 | 94.6 |
| Adjusted coefficient of determination $R^2$ | 0.419 | |

**Table 3.** Multivariate analysis with motor FIM on admission restricted to narrow bands.

| Motor FIM on admission | 35−42 points | 43−50 points | 51−58 points | 59−66 points | 67−74 points | 75−82 points | 83−90 points |
|---|---|---|---|---|---|---|---|
| Number of patients | 87 | 100 | 100 | 96 | 86 | 112 | 138 |
| | CE | CE | CE | CE | CE | CE | CE |
| Age | −0.196 | −0.311 | −0.165 | −0.192 | −0.122 | −0.082 | −0.023 |
| Duration from onset to admission | | −0.352 | −0.255 | −0.118 | −0.101 | −0.079 | |
| Duration of hospitalization | 0.072 | 0.047 | | | 0.030 | 0.032 | |
| Motor FIM on admission | | | −0.773 | −0.477 | −1.033 | −0.620 | −0.806 |
| Cognitive FIM on admission | 0.630 | 0.310 | | | 0.147 | 0.173 | |
| Adjusted coefficient of determination $R^2$ | 0.164 | 0.336 | 0.199 | 0.202 | 0.446 | 0.423 | 0.622 |

CE, Coefficient of regression.

**Table 4.** Adjusted motor FIM gain.

| Age | | 74 years old or younger | | | 75 years old or older | | | Mean | Adjusted mean |
|---|---|---|---|---|---|---|---|---|---|
| Motor FIM on admission | | 13−38 points | 39−64 points | 65−90 points | 13−38 points | 39−64 points | 65−90 points | | |
| Number of patients | Dementia | 175 | 70 | 37 | 181 | 46 | 26 | 535 | − |
| | Non-dementia | 41 | 116 | 214 | 26 | 80 | 89 | 566 | − |
| Standard severity distribution | | 0.072 | 0.205 | 0.378 | 0.046 | 0.141 | 0.157 | 1 | − |
| Age | Dementia | 63.0 | 58.4 | 58.9 | 81.8 | 82.0 | 81.4 | 71.0 | 67.0 |
| | Non-dementia | 62.8 | 61.4 | 58.6 | 81.1 | 80.3 | 79.7 | 66.9 | − |
| Motor FIM on admission | Dementia | 20.0 | 49.2 | 75.5 | 19.1 | 49.9 | 74.8 | 32.6 | 59.8 |
| | Non-dementia | 28.4 | 52.4 | 79.9 | 29.4 | 52.4 | 77.8 | 64.0 | − |
| Motor FIM gain | Dementia | 29.4 | 27.7 | 10.6 | 13.8 | 19.6 | 7.7 | 20.7 | 16.5 |
| | Non-dementia | 36.4 | 28.4 | 8.0 | 31.6 | 24.4 | 7.7 | 17.6 | − |

Standard severity distribution: number of non-dementia patients in six groups divided by 566 (for example, standard severity distribution of 0.072 for patients 74 years or younger with motor FIM scores of 13 to 38 was obtained by dividing 41 by 566).
Adjusted mean: Data in non-dementia patients multiplied by standard severity distribution (for example, the adjusted motor FIM gain of 16.5 points in dementia patients=29.4*0.072+27.7*0.205+10.6*0.378+13.8*0.046+19.6*0.141+7.7*0.157).

conclusion. Therefore even if there is an association between cognitive FIM on admission and motor FIM gain (motor FIM gain increases with higher cognitive FIM on admission), or if dementia patients have significantly poorer outcomes of rehabilitation than non-dementia patients, it is impossible to conclude that motor FIM gain increases with higher cognitive FIM on admission. This may be because many dementia patients have low motor FIM on admission (correlation between motor FIM and cognitive FIM), and many are also elderly (presence of a confounding factor). Multivariate regression analysis may be performed to exclude this effect. In multivariate regression analysis, the coefficient of regression for age is negative, leading to the conclusion that motor FIM gain decreases with advancing age. However, the fact that the coefficient of regression for motor FIM and cognitive FIM on admission are negative cannot lead to the conclusion that motor FIM gain decreases with higher FIM on admission. This is due to the ceiling effect.

The mean motor FIM gain was greatest when motor FIM on admission was 33−36 points, and the mean cognitive FIM gain was greatest when cognitive FIM on admission was 13−16 points [3]. The association between FIM on admission and FIM gain was thus not linear, but exhibited a peak toward the lower end of FIM on admission. When multiple regression analysis of all subjects was performed, as there were more patients with motor FIM on admission of 35−91 points (for whom the correlation coefficient between motor FIM on admission and motor FIM gain was negative) than with 13−34 points (for whom the correlation coefficient between motor FIM on admission and motor FIM gain was positive), the coefficient of regression for motor FIM on admission becomes negative.

Most previous studies that have demonstrated the effect of cognitive ability on ADL gain and ADL efficiency in stroke patients have used FIM effectiveness to correct the ceiling effect [6−9]. In the present study also, we found that the multiple regression analysis using FIM effectiveness of Study 1 (Table 2) yielded positive coefficients of regression for both motor FIM and cognitive FIM on admission. However, FIM effectiveness is also an index that is dependent on FIM on admission. Recently, Tokunaga *et al.* corrected motor FIM effectiveness so that it constitutes an index independent of motor FIM on admission, by correcting the value of A in the equation motor FIM gain/(A − motor FIM on admission) to 42, 64, 79, 83, 87, 89, and 91 points (for motor FIM on admission of 13−18 points, 19−24 points, 25−30 points, 31−36 points, 37−42 points, 43−48 points, and 49−90 points, respectively) [10].

We have been unable to locate any studies that have investigated the effect of cognitive ability on ADL gain by restricting motor FIM on admission to narrow bands. Motor FIM on admission was not selected as an explanatory variable (no difference in motor FIM on admission between patients in the same group) only for patients with motor FIM on admission of 35−50 points, but the coefficient of regression for cognitive FIM on admission was positive in both this range and for patients with motor FIM on admission of 67−82 points, meaning that this method was also capable of demonstrating that motor FIM gain increases with higher cognitive FIM on admission.

Multiple regression analysis has the advantage that it is possible to correct for the influence of numerous confounding factors, but still entails the problem that numerous factors in addition to FIM on admission do not necessarily exhibit a linear relationship (a straight-line relationship between the factor concerned and motor FIM gain). For example, in multiple regression analysis, although an increase in age of 1 year decreases motor FIM gain by a certain number of points according to a linear relationship, the effect of age on FIM gain differs according to FIM on admission [11, 12]. Accordingly, the effect of cognitive FIM on admission on motor FIM gain must be investigated in detail, such as in terms of the range of motor FIM on admission, or of the effect of cognitive FIM on admission on motor FIM gain within a particular group. Performing multiple regression analysis with motor FIM on admission restricted to narrow bands is effective for this purpose.

The use of a standard severity distribution has been reported by Tokunaga *et al.* [13−17], and has been used to date as the standard severity distribution for all patients in a region to correct ADL gain in different hospitals [13,14], ADL efficiency [15], and duration of hospitalization and rate of discharge to home [16] to make inter-hospital comparisons. The standard distribution of severity for non-smokers has also been used to correct the mean FIM gain of smokers in order to compare the FIM gain between smokers and non-smokers [17]. In the present study, we used this method to show that the adjusted mean motor FIM gain was lower for dementia patients than for non-dementia patients. This method, however, has the problems that it cannot be used to make statistical comparisons, or to correct for confounding factors other than age and motor FIM on admission.

Although there are issues with all three methods, all of them were capable of showing that motor FIM gain increased with higher cognitive FIM on admission.

The following issues can be raised concerning our study. First, we were unable to clarify the relative merits of these three methods.

Secondly, because cognitive FIM has been reported as a similarly appropriate method of evaluating cognitive ability in stroke patients as the Mini Mental State Examination (MMSE) [18], in our investigation we categorized dementia as a cognitive FIM score of 25 points or more, but in fact the MMSE or the revised Hasegawa Dementia Scale (HDS-R) should have been used as a screening test to divide the population into patients with and without a decline in cognitive ability.

Thirdly, in this study we divided patients differently for each separate investigation, but there are no clear criteria for the most appropriate number of groups into which they should be divided.

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