Japanese Journal of Comprehensive Rehabilitation Science (2020)

Original Article

Explanatory variables to use in a multiple regression analysis to predict stroke patients' motor FIM score at discharge from convalescent rehabilitation wards: an investigation of patients with a motor FIM score of less than 40 points at admission

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ABSTRACT
Tokunaga M, Sannomiya K. Explanatory variables to use in a multiple regression analysis to predict stroke patients' motor FIM score at discharge from convalescent rehabilitation wards: an investigation of patients with a motor FIM score of less than 40 points at admission. Jpn J Compr Rehabil Sci 2020; 11: 102-108.
Objective: This study aimed to clarify the explanatory variables to use in a multiple regression analysis to predict improvement in the motor Functional Independence Measure (FIM) during the hospitalization of patients with severe stroke in a convalescent rehabilitation ward.
Methods: The subjects of this study were 230 patients with stroke with a motor FIM score of less than 40 points at admission. In total, 17 factors were stratified and those with a significant difference in motor FIM effectiveness between stratified groups were used as the explanatory variables of a stepwise regression analysis, which employed the motor FIM score at discharge as the objective variable.
Results: There were significant differences in motor FIM effectiveness among the 12 factors. The 10 factors selected through a stepwise regression analysis were age, cognitive FIM score at admission, motor FIM score at admission, number of days from onset to admission, modified Rankin Scale before onset, Brunnstrom stage of paralyzed lower limb, body mass index, sitting stability, Japan Coma Scale, and hemispatial neglect.
Conclusion: It is desirable to use these 10 factors as explanatory variables in multiple regression analyses.
Key words: stroke, multiple regression analysis, FIM improvement, set of explanatory variables to be used, patients with low FIM scores at admission

Introduction

Predicting outcomes is important for planning and executing treatment plans in rehabilitation medicine. Multiple regression analysis, which is a multivariate analysis, is often used to predict outcomes such as the Functional Independence Measure (FIM) [1] at discharge and FIM gain (FIM at discharge minus FIM at admission). However, the prediction accuracy of a multiple regression analysis is not as high as expected. In a report by Heinemann et al. [2], which reviewed papers on prediction using multiple regression analyses, the square of the multiple regression coefficient (coefficient of determination) was 0.46−0.73. This is a level at which the tendency of a group can be predicted, but is not sufficient for predicting individual cases [3].

To improve the accuracy of predicting motor FIM (mFIM) improvement through a multiple regression analysis, three methods were reported: 1) conversion of mFIM at admission to a reciprocal number (1/mFIM at admission) and using it as one of the explanatory variables [4], 2) predicting mFIM improvement rate (mFIM effectiveness) through a multiple regression analysis and converting it to mFIM at discharge [5], and 3) creating two prediction formulas using the data of patients with low and high mFIM at admission [6]. However, these methods deal with the problem of the ceiling effect of mFIM gain (small mFIM gain in patients with high mFIM score at admission) [7, 8]. These methods significantly improved prediction accuracy in the high mFIM group (patients with an mFIM score

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Accepted: September 12, 2020.
No benefits in any form have been or will be received from any commercial party related directly or indirectly to the subject of this manuscript.

doi.org/10.11336/jjcrs.11.102

at admission of 40−90 points) with the ceiling effect, but did not improve the prediction accuracy for the low mFIM group (patients with mFIM score at admission of 13−39 points) [8]. It is important to use the appropriate explanatory variables to improve prediction accuracy in the low mFIM group.

In a review of 35 papers that predicted FIM improvement in patients with stroke hospitalized in convalescent rehabilitation wards in Japan using a multiple regression analysis (hereafter, multiple regression analysis predicting FIM improvement in stroke), explanatory variables which were used in more than four papers and were significant in more than half the studies were only nine factors [9, 10]. These included mFIM score at admission (significant in 26 papers, used in 29 papers, hereafter written as 26/29), age (23/32), cognitive functions such as cognitive FIM (cFIM) score at admission (15/15), length of hospital stay (8/14), number of days from onset to admission (9/17), modified Rankin Scale (mRS) before onset (4/5), training time (3/5), body mass index (BMI) (3/5), and Brunnstrom stage (2/4) [9, 10]. The Japanese Society of Rehabilitation Medicine recommended the use of six factors other than those described above when conducting clinical research or surveying stroke [11]. These factors were sex, stroke type, laterality of the lesion, whether the lesion was above or below the cerebellum tent, hemispatial neglect, and aphasia [11]. Furthermore, it was reported that trunk function [12] and the Japan Coma Scale (JCS) [13] are useful for predicting outcomes in the low mFIM group. Therefore, the abovementioned 17 factors are promising candidates for the explanatory variables that should be used in a multiple regression analysis to predict mFIM improvement in patients with stroke. However, no reports have used all 17 factors as explanatory variables. In addition, it is not clear which factor has a large influence on mFIM improvement.

In this study, we performed a multiple regression analysis in patients with stroke, hospitalized in a convalescent rehabilitation ward, and whose mFIM score was less than 40 points at admission. The purpose of this study was to clarify which of the above 17 explanatory variables had a large influence on mFIM improvement and to propose a set of explanatory variables that should be used in a multiple regression analysis to predict mFIM improvement.

Subjects and methods

The subjects consisted of patients with stroke admitted to the convalescent rehabilitation ward at K hospital between January 1, 2013 and March 31, 2020, and those with an mFIM score at admission of 13−39 points. The following patients were excluded to eliminate the effects of exceptional patients: those with subarachnoid hemorrhage, those who had been admitted within 4 days or more than 60 days after onset, those who had spent less than 30 days or more than 180 days in the hospital, those with an mFIM gain of less than 0 points, and bilateral hemiplegia. In total, 230 patients were included in this study.

We retrospectively surveyed the 17 factors described above, namely sex, age, type of stroke (cerebral infarction or cerebral hemorrhage), paralyzed side (right or left), whether the lesion was above or below the cerebellum tent, mRS before onset, number of days from onset to admission, mFIM score at admission, cFIM score at admission, BMI, JCS, Brunnstrom stage of paralyzed lower limb, presence or absence of hemispatial neglect, presence or absence of aphasia, sitting stability, training time, and length of hospital stay, as well as mFIM score at discharge. Training time was the total number of units of physical therapy and occupational therapy per day (1 unit was 20 min of training). For sitting stability, we classified bedridden and sitting with backrest leaning as unstable and independent sitting as stable [14].

1. mFIM effectiveness in the stratified groups

We compared the mFIM effectiveness between the two groups in terms of sex, stroke type, paralyzed side, above or below the cerebellum tent, hemispatial neglect, aphasia, and sitting stability. Age, number of days from onset to admission, mFIM at admission, cFIM at admission, training time, and length of hospital stay were compared for the two groups below and above the median value. Since no patients had a JCS of 100−300 points, a comparison of the two groups of 0−3 points and 10−30 points was performed. BMI was initially divided into three groups: less than 18.5 kg/m^2 (underweight), 18.5−27.5 kg/m^2 (normal weight and overweight), and above 27.5 kg/m^2 (obese) [15]. However, since the obese group included only 16 cases, two groups were compared: less than 18.5 kg/m^2 and 18.5 kg/m^2 or more. The mRS before onset (0−1, 2−3, 4−5) and Brunnstrom stage (I−II, III−IV, V−VI) of three groups were compared. mFIM effectiveness was calculated as mFIM gain/(91 points − mFIM score at admission) [16]. mFIM gain, which is the mFIM improvement score, is strongly affected by the ceiling effect, whereas mFIM effectiveness, which is the mFIM improvement rate, is less likely to be affected by mFIM score at admission and is more frequently used in the study of mFIM improvement than mFIM gain [16].

A Mann-Whitney *U* test was used to compare the two groups. The Kruskal-Wallis test was used to compare multiple groups, and if there was a significant difference, multiple comparisons were performed using the Steel-Dwass method. The level of significance was <5%.

2. Multiple regression analysis with mFIM score at discharge as the objective variable

Of the 17 factors in Study 1, 12 factors that differed significantly between the groups were used as explanatory variables in a stepwise regression analysis with mFIM score at discharge as the objective variable. A factor with an *F* value of two or more was selected as a valid explanatory variable. Age, number of days from onset to admission, mFIM score at admission, cFIM score at admission, and training time were input as numerical values. The mRS before onset (0−5) and Brunnstrom stage (I−VI) were input as ordinary scale values. The JCS (0, 1, 2, 3, 10, 20, 30) has a large numerical difference between 1 and 2 digits, and so it is not appropriate to input a numerical value. Thus, a dummy variable was created [17]. Specifically, JCS 0 point was set to 0,0; JCS 1−3 points were set to a 1-digit dummy of 1,0; and JCS 10−30 points were set to a 2-digit dummy of 0,1. For stroke type, cerebral infarction was set as 0, and cerebral hemorrhage as 1. Regarding hemispatial neglect and aphasia, absent was set as 0 and present as 1. For sitting stability, unstable was set as 0 and stable as 1. Since there is no linear relationship between BMI and mFIM improvement [18], BMI < 18.5 kg/m^2 was set as 0 and 18.5 kg/m^2 or more as 1. We then investigated the standard partial regression coefficient β, which means the relative strength of the explanatory variable to the objective variable. The statistical software used was four-steps EXCEL statistics [19].

Results

Table 1 shows the basic attribute data of the 230 target patients. The average mFIM score at admission was 21.0 points.

Among the 17 factors, mFIM effectiveness differed significantly between the stratified groups of 12 factors, namely age, stroke type, mRS before onset, number of days from onset to admission, mFIM at admission, cFIM at admission, BMI, JCS, Brunnstrom stage of paralyzed lower limb, hemispatial neglect, sitting stability, and training time (Table 2). There were no significant differences between the stratified groups in five factors, namely sex, paralyzed side, above or below the cerebellum tent, aphasia, and length of hospital stay.

Among the 12 factors that were significant in Study 1, there was no correlation coefficient of

Table 1. The basic attribute data of the subjects.

Number of patients	230
Sex	Male 127, female 103
Age	72.4±13.1 (28−93)
Type of stroke	Infarction 109, hemorrhage 121
Paralyzed side	Right 113, left 117
Above or below the cerebellum tent	Above 205, below 25
Modified Ramkin Scale before onset	(0) 151, (1) 23, (2) 18, (3) 21, (4) 13, (5) 4
Number of days from onset to admission	17.2±8.1 (5−56)
Motor FIM score at admission	21.0±8.8 (13−39)
Cognitive FIM score at admission	15.5±7.8 (5−35)
Body mass index (BMI)	21.9±3.7 (14.7−36.2) (<18.5) 38, (18.5− 27.4) 176, (≥27.5) 16
Japan Coma Scale (JCS)	(0) 43, (1) 52, (2) 40, (3) 74, (10) 16, (20) 2, (30) 3
Brunnstrom stage of paralyzed lower limb	(I) 52, (II) 65, (III) 22, (IV) 32, (V) 42, (VI) 17
Hemispatial neglect	Absent 143, present 87
Aphasia	Absent 141, present 89
Sitting stability	Unstable 177, stable 53
Training time (units/d)	5.7±0.8 (4−7)
Length of hospital stay	117.9±33.8 (31−179)
Motor FIM score at discharge	46.4±23.8 (13−90)
Motor FIM gain	25.4±19.8 (0−70)
Motor FIM effectiveness	0.379±0.088 (0−0.982)

Abbreviation: FIM, Functional Independence Measure.
Data for this study are expressed as number of patients or mean±standard deviation (minimum to maximum).

0.6 or more; thus, there was no multicollinearity. When a stepwise regression analysis was performed with the 12 factors as explanatory variables and mFIM score at discharge as the objective variable, a significant prediction formula was obtained (Table 3). The coefficient of determination was 0.707

Table 2. Comparison of motor FIM effectivemess in stratified groups.

Factor	Motor FIM effectiveness	p Value
Sex	Male 0.391±0.295, female 0.364±0.300	0.52
Age	<73 yaers old 0.524±0.291, ≧73 years old 0.254±0.241	＜0.001
Type of stroke	Infarction 0.326±0.274, hemorrhage 0.426±0.310	＜0.05
Paralyzed side	Right 0.384±0.308, left 0.374±0.287	0.86
Above or below the cerebellum tent	Above 0.376±0.294, below 0.404±0.326	0.68
Modified Ramkin Scale (mRS) before onset	mRS 0−1 0.415±0.301, mRS 2−3 0.281±0.252, mRS 4−5 0.228±0.262	＜0.01*
Number of days from onset to admission	<13 d 0.482±0.310, ≥13 d 0.337±0.282	＜0.01
Motor FIM score at admission	<21 points 0.266±0.275, ≥21 points 0.544±0.247	＜0.001
Cognitive FIM score at admission	<16 points 0.251±0.252, ≥16 points 0.536±0.273	＜0.001
Body mass index (BMI)	<18.5 kg/m2 0.213±0.259, ≥18.5 kg/m2 0.411±0.294	＜0.001
Japan Coma Scale (JCS)	JCS 0−3 0.396±0.293, JCS 10−30 0.205±0.291	＜0.01
Brunnstrom stage (BRS) of paralyzed lower limb	BRS I−II 0.326±0.294, BRS III−IV 0.428±0.288, BRS V−VI 0.438±0.296	＜0.05**
Hemispatial neglect	Absent 0.432±0.307, present 0.290±0.258	＜0.05
Aphasia	Absent 0.388±0.295, present 0.364±0.301	0.57
Sitting stability	Unstable 0.327±0.291, stable 0.552±0.250	＜0.001
Training time	<6 units/d 0.207±0.226, ≥6 units/d 0.414±0.298	＜0.001
Length of hospital stay	<118 d 0.349±0.301, ≧118 d 0.406±0.292	0.11

Numerical value, mean±standard deviation of motor FIM effectiveness; p value, comparison between stratified groups (Mann-Whitney U test or Kruskal-Wallis test); <0.01*, significant between mRS 0−1 and mRS 2−3, between mRS 0−1 and 4−5; <0.05**, significant between BRS I−II and BRS V−VI.

Table 3. Stepwise regression amalysis with motor FIM score at discharge as the objective variable.

	Standard partial coefficient β	Partial coefficient B	Standard error	F value
Age	−0.381	−0.691	0.071	94.5
Cognitive FIM at admission	0.298	0.909	0.146	38.9
Motor FIM at admission	0.235	0.634	0.148	18.2
Number of days from onset to admission	−0.200	−0.591	0.112	27.7
Modified Rankin Scale (mRS) before onset	−0.135	−2.351	0.692	11.5
Brunnstrom stage of paralyzed lower limb	0.108	1.547	0.647	5.7
Body mass index (BMI)	0.095	6.085	2.440	6.2
Sitting stability	0.089	5.018	2.475	4.1
2-digit dummy of Japan Coma Scale (JCS)	−0.088	−7.228	3.216	5.1
Hemispatial neglect	−0.058	−2.845	1.987	2.0

Constant: 72.0, p value of the prediction formula: <0.001, coefficient of determination R^2: 0.707. The explanatory variables are aranged in descending order of the standard partial regression coefficient β.

The predicted value for motor FIM score at discharge = − 0.691 × age+0.909 × cognitive FIM score at admission + 0.634 × motor FIM score at admission − 0.591 × number of days from onset to admission − 2.351 × mRS before onset + 1.547 × Brunnstrom stage + 6.085 × BMI (<18.5 kg/m^2: 0, ≥18.5 kg/m^2: 1) + 5.018 × sitting stability (unstable: 0, stable: 1) − 7.228 × two-digit dummy of JCS (0and 1-digit: 0, 2-digit: 1) − 2.845 × hemispatial neglect (absent: 0, present: 1).

and coefficient of determination with adjusted degrees of freedom was 0.694. Of the 12 explanatory variables, 10 variables, excluding stroke type and training time, were selected as valid explanatory variables.

The absolute value of the standard partial regression coefficient β was large in the following order: age, cFIM at admission, mFIM at admission, number of days from onset to admission, mRS before onset, Brunnstrom stage of paralyzed lower limb, BMI, sitting stability, 2-digit dummy of JCS, and hemispatial neglect.

Discussion

This study set 17 factors as candidates for the explanatory variables: 9 factors frequently used in multiple regression analyses predicting FIM improvement in stroke, 6 recommended by the Japanese Society of Rehabilitation Medicine, and 2 useful for predicting outcomes for the low mFIM group. Twelve factors, which differed significantly in mFIM effectiveness between the stratified groups, were used as explanatory variables in the stepwise regression analysis, and 10 were selected as valid explanatory variables. We clarified that the order of explanatory variables with a large standard partial regression coefficient β was age, cFIM at admission, mFIM at admission, number of days from onset to admission, mRS before onset, Brunnstrom stage of paralyzed lower limb, BMI, sitting stability, 2-digit dummy of JCS, and hemispatial neglect.

The main features of this study were as follows: 1) it focused on patients with an mFIM of less than 40 points at admission, 2) it objectively selected explanatory variables that should be used in a multiple regression analysis, and 3) it revealed the order of explanatory variables with a large standard partial regression coefficient β. These points are discussed below.

1. Reasons for limiting the target to patients with an mFIM score of less than 40 points at admission

The magnitude of the effect of factors on mFIM improvement varies depending on the patient population. In other words, the influence of inhibiting factors is not uniform, but instead differs according to the degree of activities of daily living (ADL) at admission [12, 20]. Therefore, it is necessary to stratify patients. Although methods have been reported to improve prediction accuracy in the high mFIM group [4−6], these methods were not effective in the low mFIM group [8]. In this study, we aimed to improve the prediction accuracy of the low mFIM group by using appropriate explanatory variables.

2. Objective selection of explanatory variables that should be used in multiple regression analysis

There are many factors which inhibit rehabilitation. A review by Hasegawa [21] confirmed as many as 60 factors. Kwakkel et al. [22] reported that valid predictors for functional recovery after stroke were age, previous stroke, urinary continence, consciousness at onset, disorientation in time and place, severity of paralysis, sitting balance, admission ADL score, level of social support, and metabolic rate of glucose outside the infarct area in hypertensive patients. In a multiple regression analysis, the number of patients should be more than 10 or 15 times the number of explanatory variables [23]. Therefore, the number of explanatory variables must be restricted in studies with a limited number of patients. The factors that the authors considered necessary were used as explanatory variables; thus, the explanatory variables differed greatly depending on the report [9, 10]. This study proposes ten factors that were objectively selected as a set of explanatory variables that should be used in multiple regression analyses predicting mFIM improvement in stroke.

The 10 explanatory variables to be used may seem too few. However, a review of 19 reports of multiple regression analyses predicting FIM improvement in stroke indicated that while each used 4−18 (median 7.5) explanatory variables, only 1−8 (median 4) were significant [10]. The 10 explanatory variables comprise the basic set, and researchers are free to add new factors that they would like to examine.

3. Order of standard partial regression coefficient β

In a review of 16 reports of multiple regression analyses predicting FIM improvement in stroke, the standard partial regression coefficient β tended to be larger in mFIM at admission, cFIM at admission, and age, but the order differed for each report [9]. In this study, β was the largest in the order of age, cFIM at admission, and mFIM at admission. The β of age was the largest, implying that age had the largest effect on mFIM improvement. In a decision tree analysis with mFIM score at discharge as the objective variable, trunk function affected outcomes in patients with mFIM scores of less than 19 points at admission, cognitive function affected outcomes in those with 31−53 points, and age affected outcomes in those with less than 54 points [12]. Since our study limited patients to those with an mFIM score of less than 40 points at admission, the effect of age might be more pronounced than in previous studies targeting all patients.

Frequently used explanatory variables and necessary explanatory variables

A comparison of the 9 explanatory variables frequently used in the reviewed 35 reports of multiple regression analyses predicting FIM improvement in stroke [9, 10] and 10 explanatory variables used in this study shows that 7 variables—age, cFIM at admission, mFIM at admission, number of days from onset to admission, mRS before onset, Brunnstrom stage of paralyzed lower limb, and BMI—were common.

On the other hand, length of hospital stay and training time were only included in the former reviews [9, 10], and JCS, sitting stability, and hemispatial neglect only in the latter (present study).

Because patients with a longer hospital stay tended to be more severely affected, previous studies targeting all patients associated a longer hospital stay with poor mFIM improvement. On the other hand, there was no difference in mFIM effectiveness between the two groups divided by the length of hospital stay in this study, which focused on the low mFIM group.

Regarding training time, 9 units (3 hours) per day of rehabilitation is allowed for stroke patients under the age of 85 years in Kumamoto Prefecture. However, for patients aged more than 85 years, the upper limit is 6 units (2 hours). Therefore, the training time depends on age. Accordingly, we conducted an additional study focusing on patients aged less than 85 years. Training time was not selected as a valid explanatory variable. A retrospective study cannot reveal the relationship between training time and mFIM improvement; it can only reveal the relationship between "why this patient was prescribed this training time" and mFIM improvement. To accurately evaluate the relationship between training time and mFIM improvement, it is necessary to conduct a prospective study in which a training time of 1 to 9 units per day is randomly assigned.

Regarding JCS, sitting stability, and hemispatial neglect, in a review of 35 reports using multiple regression analyses predicting FIM improvement in stroke, hemispatial neglect was used in one study, but JCS and sitting stability were not used at all [10]. It is hoped that these three factors will be frequently used in multiple regression analyses in the future.

Difficulty in predicting mFIM score at discharge using only admission data

FIM may dramatically improve in patients who have inhibiting factors for rehabilitation such as impaired consciousness or total aphasia at the time of admission and whose symptoms improve after admission [24]. Therefore, comorbidities may be a predictor of a low mFIM score at discharge (poor improvement) and of a high mFIM score at discharge (good improvement). Since there is a limit to accurately predicting mFIM score at discharge using only data obtained at the time of admission, some studies added mFIM improvement at two weeks [25] or one month [26] to the explanatory variables, and thus improved the prediction accuracy of the mFIM score at discharge.

Conclusion

This study identified 10 explanatory variables that should be used in multiple regression analyses to predict mFIM improvement in stroke. It is hoped that other useful explanatory variables not studied in this research will be added to this set in the future to further improve the prediction accuracy of multiple regression analyses.

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