Effects of the Interaction among Motor Functions on Self-care in Individuals with Stroke

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Background: No study to date has focused on what combinations of motor functions are strongly associated with self-care independence in individuals with stroke. The purpose of this study is to clarify the impact of motor function interactions on self-care independence in individuals with stroke. *Methods:* This retrospective observational study included 132 individuals with first stroke. We conducted a decision tree analysis to examine the impact on daily living skills of numerous key functions − the upper and lower limbs on the affected side, bilateral grip strength and lower limb muscle strength on the unaffected side, bilateral upper limb and trunk function, and balance. Further, we confirmed the interaction effects detected via the decision tree approach using logistic regression. *Results:* As per the decision tree analysis, the interaction between balance and upper limb function of the affected side showed an association with self-care independence. The interaction terms of balance and upper limb function we analyzed were significantly associated with the ability to achieve self-care independence, after some adjustments to eliminate the influence of confounding factors. *Conclusions:* These results suggest that the combination of functional status of balance and upper limb function of the affected side are strongly associated with the independence of self-care. The decision tree created in this study could serve as an effective guide when implementing a remedial approach for individuals with stroke aiming to achieve self-care independence.
Key Words: Self-care—rehabilitation—balance—upper limb function—interaction—decision tree

Introduction

Stroke is a major cause of serious disability.[1,2] It not only impairs movement of the limbs on the side contralateral to the affected cerebral hemisphere but also causes various functional disorders, including muscle weakness and impaired dexterity on the same side as the affected cerebral hemisphere, unilateral spatial neglect, and cognitive dysfunction.[3−6] These sequelae often significantly hinder the functional independence of individuals with stroke.[3,6] Compared with other conditions (e.g., musculoskeletal disorder, heart conditions), stroke is strongly associated with severe disability and can lead to material deficits in many areas, such as reaching, dexterity, and communication.[2]

Rehabilitation can be highly productive in helping individuals with stroke to return to their normal lifestyle. For individuals with stroke, rehabilitation primarily focuses on issues relating to self-care and returning home.[7] In therapies aimed at improving the level of independent self-care, physical exercises are often performed in conjunction with the repeated practice of self-care tasks to improve impaired cognitive and physical functioning (e.g., sitting balance, trunk and upper limb control, and upper limb therapeutic exercises).[8−10] For example, in

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training to get dressed, patients are encouraged to frequently perform various tasks, not only the repeated practice of self-care using cueing and one-handed techniques but also various remedial steps such as using a neurodevelopmental approach, doing table-top activities, and performing balance exercises.[9,10]

To effectively utilize the recovery of cognitive and physical functions using a remedial approach for self-care, it is important for therapists to understand the relationship of both cognitive and physical functioning to self-care. Reports to date indicate that the level of independent self-care of individuals with stroke is directly related to the degree of motor and sensory functioning of the upper and lower limbs on the affected side,[3,11−13] trunk function and balance,[12,14] upper limb function of the unaffected side,[15] unilateral spatial neglect,[6,12,16] and cognitive dysfunction.[12] In addition, it has been suggested that motor functions are strongly associated with the level of independent self-care compared with perceptual and cognitive functions.[12] However, to our knowledge, no study to date has focused on what combinations of motor functions are strongly associated with self-care independence. Therefore, the interaction among motor functions in relation to self-care in individuals with stroke remains remarkably unclear. The purpose of this study is to clarify the impact of motor function interactions on self-care independence in individuals with stroke. The findings obtained may help us to understand the relationship between independent self-care and motor function, which we expect will be highly useful in developing an effective intervention strategy aimed at greatly improving independent self-care.

Methods

In this retrospective observational study, we accumulated and analyzed medical chart data from patients who had already been discharged. We analyzed the data of 132 individuals with stroke who received treatment in the rehabilitation ward of a hospital in Japan and who satisfied the following inclusion criteria: (1) discharged during the period between April 2011 and December 2017, (2) diagnosed with first-onset cerebral hemorrhage or cerebral infarction, (3) having a unilateral supratentorial lesion, (4) without marked impairment of cognitive function and unilateral spatial neglect ($\geq$21 points on the revised Hasegawa Dementia Scale[17] and 3 points for visuospatial perception on the Stroke Impairment Assessment Scale (SIAS),[18] and (5) without missing data for the analysis items. As a rule, during their hospital stay, all patients received occupational therapy, physical therapy, and speech therapy as needed for 2-3 hours on weekdays and Saturdays, and 1-2 hours on Sundays and public holidays. This present study was conducted after it was reviewed and approved by the ethical review boards of Kita-Fukushima Medical Center and Tohoku Fukushi University [No.72, RS180601].

From the medical charts of the subjects, we extracted numerous data series regarding self-care and motor functioning. As indicators of the level of self-care independence, we used 4 items from the Barthel Index[19]: feeding, grooming, toileting, and dressing. To evaluate motor function, we analyzed the operational capabilities of the upper and lower limbs on the affected side, bilateral grip strength and lower limb muscle strength on the unaffected side, bilateral upper limb and trunk function, and balance. The SIAS[18] was used as an indicator of upper and lower limb motor function on the affected side and to evaluate the trunk function and lower limb muscle strength of the unaffected side. The SIAS is often used to comprehensively evaluate functions that are frequently impaired by stroke. The SIAS test of motor function of the affected side comprises 5 tests: knee-mouth, finger-function, hip-flexion, knee-extension, and foot-pat. These tests together evaluate the proximal and distal muscles of the upper and lower limbs individually. For each test, the ability to perform the exercise tasks and the smoothness of tasks performed is scored with 0-5 points, where higher scores indicate better motor function. The SIAS trunk function items, which consist of verticality and abdominal muscle strength tests, as well as the SIAS knee-extension strength test on unaffected side, are both scored with 0-3 points according to the state of functioning. Grip strength was evaluated using a grip dynamometer. As an indicator of upper limb function, we used the simple test for evaluating hand function (STEF), which is widely used in Japan.[20] The STEF is an instrument that was developed to evaluate the capacity of upper limb function, where subjects are required to move 10 types of objects of differing size, form, weight, and material. The time required to move each object was scored with 0-100 points, with higher scores indicating better upper limb function. As an indicator of balance, we used the Berg balance scale (BBS),[21] which comprises 14 tasks; each task is scored with 0-4 points (maximum of 56 total points), with higher scores indicating better functioning. The Barthel Index, STEF, and grip strength tests were conducted by occupational therapists, whereas the SIAS and BBS tests were conducted by physical therapists.

Prior to our detailed statistical analyses, subjects were classified into 2 categories: the independent group (patients able to independently perform all of the 4 items in the Barthel Index [feeding, grooming, toileting, and dressing] and the dependent group (patients with low scores for one or more of these items). First, to determine which motor functions differed between the 2 groups, we compared patient characteristics and each variable of the above-mentioned motor functions using the Mann−Whitney U test. Next, to elucidate what combinations of interacting motor functions are associated with self-care independence, we conducted a decision tree analysis (classification and regression trees) to find items with a high detectability of interaction.[22] In the decision tree, items showing a significant difference in the intergroup comparison were considered independent variables, and the independent/dependent groups were treated as dependent variables. In the present study, using the Gini Index for the decision tree classification criteria, the minimum number of cases from the preanalysis group (parent node) was set at 10, and the minimum number of cases of the postanalysis group (child node) was set at 3. Furthermore, to prevent overfitting, we conducted cost complexity pruning (±1 standard deviation). To perform a multivariate analysis using interaction terms discussed below, the maximum decision tree depth was set at 2.

The relationships among variables selected decision tree were examined using Spearman's rank correlation. Further, to clarify the impact of the interactions detected by the decision tree after adjusting for the effects of confounding factors, we conducted a logistic regression analysis (forced entry), using interaction terms that were created by multiplying binarized variables based on the classification standard on the decision tree. The crude model was created by simple logistic regression analysis with the independent/dependent group as dependent variables, and the variables selected by the decision tree, together with the interaction terms of these, as independent variables. The adjusted version of the model was created using multiple logistic regression analysis, employing the same variables as crude model as independent variables and variables significant in the inter–group comparison as moderator variables. Furthermore, centralization was performed when creating the interaction terms to avoid multicollinearity. Moreover, when the correlation coefficient of variables entered as moderator variables was greater than .7, analysis was performed only after removing 1 variable. In addition, to examine the effect of interactions in detail, subjects were classified into 4 groups according to the combination of the variables selected on the decision tree: Group 1, low "variable A" and low "variable B"; Group 2, low "A" and high "B"; Group 3, high "A" and low "B"; Group 4, high "A" and high "B." Multivariate logistic regressions were performed with these groups as independent variables. Furthermore, in this analysis, both crude and adjusted models aiming at adjusting variables significant in the intergroup comparison as moderator variables were created. All statistical analyses were performed using version 25 of the SPSS system, and P less than .05 was considered statistically significant.

Results

Patient characteristics, the outcomes for cognitive and physical functions and for self-care are presented in Tables 1 and 2. The study involved 132 patients in total, including 88 (66.7%) in the independent group, and 44 (33.3%) in the dependent group. The comparison between the independent and dependent groups revealed a significant difference in all motor functions (P<0.01).

As per the decision tree analysis, the BBS score was selected as the most suitable variable for discriminating between the independent and dependent groups, and the classification cut-off was a score of 41/40 points, as illustrated in Figure 1. In the group of patients with BBS score greater than or equal to 41 points, 89.1% were in the independent group, whereas in the group with BBS score less than or equal to 40 points, 15.0% were in the independent group. In the second level of the decision tree, for the group with BBS less than or equal to 40 points, the STEF of the affected side was selected as the next classification variable, with 80/79 points as the classification cut-off. In the group with affected side STEF score less than or equal to 79 points and BBS score less than or equal to 40 points, only 8.3% were in the independent group.

There was a moderate positive correlation between BBS and affected side STEF scores (rs = 0.55, P < .01). From our logistic regression analysis we found that the BBS score, affected side STEF score, and their interaction terms showed a significant association with self-care independence in the crude model. In the adjusted model, which was coordinated for confounding factors such as age, cognitive function, and other physical functions, the interaction terms of BBS and affected side STEF were significantly associated with self-care independence (Table 3, odds ratio [OR] = .008, 95% confidence interval [CI] .000-.596, P = .028). In the analysis combining the 2-state variable, Group 1 (low BBS and low STEF) consisted of 49 patients, Group 2 (low BBS and high STEF) of 4 patients, Group 3 (high BBS and low STEF) of 43 patients, and Group 4 (high BBS and high STEF) of 36 patients. When Group 1 was used as the reference, the odds ratios for Groups 3 and 4 were .186 (95% CI .037-.931, P < .05) and .004 (95% CI .001-.024, P < .001), respectively (Table 4). After adjusting for confounding factors, the odds ratio for Group 4 was .003 (95% CI .000-.041, P < .001) when Group 1 was used as the reference.

Table 1. *Patients characteristics (n = 132)*

	Mean ± standard deviation or %
Age, y	68.4 ± 14.7
Men, %	59.1
Type of CVA	
Cerebral hemorrhage, %	24.2
Cerebral infarction, %	75.8
Right side hemiplegia, %	50.8
Time poststroke, day	57.8 ± 18.4
Time postadmission, day	29.7 ± 12.0

Abbreviations: CVA, cerebrovascular accident.

Table 2. *Comparison of characteristics and stroke-related impairments by patient groups*

	Independent (n = 88)	Dependent (n = 44)	*P* value
Age, y	66.4 ± 15.8	73.1 ± 10.8	.032
Men, %	61.4	54.5	.286
Right side hemiplegia, %	51.1	50.0	.902
Time poststroke, day	55.7 ± 19.1	62.0 ± 16.2	.115
Time postadmission, day	29.1 ± 13.1	31.0 ± 9.3	.715
Barthel Index items			
Feeding (range; 0-10)	10 (10-10)	10 (5-10)	<.001
Grooming (range; 0-5)	5 (5-5)	5 (0-5)	<.001
Toileting (range; 0-10)	10 (10-10)	5 (5-5)	<.001
Dressing (range; 0-10)	10 (10-10)	5 (5-10)	<.001
Stroke impairment assessment set			
Knee-mouth test (range; 0-5)	4 (4-5)	3 (1-4)	<.001
Finger-function test (range; 0-5)	4 (3-5)	2 (1-4)	<.001
Hip-flexion test (range; 0-5)	5 (4-5)	4 (3-4.5)	<.001
Knee-extension test (range; 0-5)	5 (4-5)	3 (2-4.5)	<.001
Foot-pat test (range; 0-5)	5 (4-5)	3 (1-4)	<.001
Verticality test (range; 0-3)	3 (3-3)	3 (3-3)	.003
Abdominal muscle strength (range; 0-3)	3 (2-3)	2 (1-3)	<.001
Unaffected side quadriceps strength (range; 0-3)	3 (3-3)	3 (2-3)	.005
Grip strength			
Affected side, kg	15.2 ± 10.9	6.4 ± 7.8	<.001
Unaffected side, kg	27.5 ± 11.4	21.2 ± 8.8	.003
Simple test for evaluating hand function			
Affected side (range; 0-100)	93.1 ± 7.2	84.0 ± 16.3	<.001
Unaffected side (range; 0-100)	66.8 ± 34.5	27.7 ± 31.9	<.001
Berg balance scale (range; 0-56)	49.7 ± 6.6	28.0 ± 15.3	<.001
Revised Hasegawa's dementia scale (range; 0-30)	27.2 ± 2.6	25.1 ± 2.5	<.001

Mean ± standard deviation or median (IQR) or %.

Discussion

The results of the present study revealed 2 useful clinical findings. First, balance and upper limb function of the affected side are strongly associated with the independence of self-care, and second, by combining the state of these 2 functions, the capability to achieve independent self-care can vary greatly. In particular, from our search of the literature, it appears that our study is the first to have demonstrated these insights.

In the present study, balance was determined to be the factor that had the greatest impact on self-care independence. Previous studies have reported that balance strongly influences independence in grooming,[23] dressing,[24,25] as well as toileting,[26] and our results here are consistent with these earlier findings. However, these studies have also

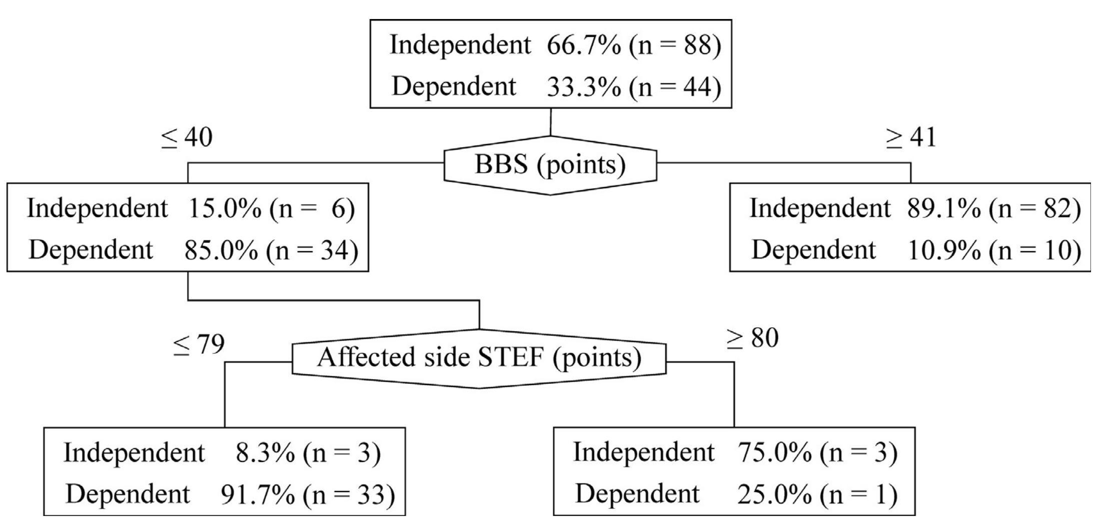

Figure 1. *CART model for discriminating between independence and dependence group in self-care.*

Table 3. *Logistic regression with interaction terms of BBS and STEF*

	Crude model[a]		Adjusted model[b]	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
BBS ≤ 40	.022 (0.007, 0.064)	<.001	.053 (.010, .290)	.001
Affected STEF ≤ 79	.056 (0.016, 0.193)	<.001	.077 (.010, .616)	.016
Interaction BBS and Affected STEF	.005 (0.000, 0.079)	<.001	.008 (.000, .596)	.028

Abbreviations: BBS, Berg balance scale; SIAS, stroke impairment assessment set; STEF, simple test for evaluating hand function.
[a]Crude model indicates results from the univariate logistic regression.
[b]Multivariate analysis with independent variables: BBS, affected STEF, and BBS*affected STEF adjusted for age, cognitive function, SIAS knee-mouth, hip-flexion, vertically, abdominal muscle strength, and unaffected side quadriceps test, and unaffected side grip strength and STEF.

Table 4. *Odds ratio of self-care independence by combining BBS and STEF*

	Crude model		Adjusted model[a]	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Group 1; BBS ≥ 41 and STEF ≥ 80 (n = 49)	1.000 (reference)		1.000 (reference)	
Group 2; BBS ≤ 40 and STEF ≥ 80 (n = 4)	.128 (.009, 1.842)	.131	.851 (.026, 27.714)	.928
Group 3; BBS ≥ 41 and STEF ≤ 79 (n = 43)	.186 (.037, .931)	.041	.337 (.041, 2.745)	.309
Group 4; BBS ≤ 40 and STEF ≤ 79 (n = 36)	.004 (.001, .024)	<.001	.003 (.000, .041)	<.001

Abbreviations: BBS, Berg balance scale; SIAS, stroke impairment assessment set; STEF, simple test for evaluating hand function.
[a]Multivariate model adjusted for age, cognitive function, SIAS knee-mouth, hip-flexion, vertically, abdominal muscle strength, and unaffected side quadriceps test, and unaffected side grip strength and STEF.

determined that, using the BBS scale, individuals with stroke require a score of 41 points for independent grooming,[23] 44 points for independent dressing.[24] In comparison, our BBS score of 41 is slightly lower, perhaps because our subject sample included individuals without clear impairment to cognitive function unilateral spatial neglect. We included such patients because we focused on the interaction among motor functions, which we believe is vital to a rigorous understanding of the functional requirements for achieving independent living.

The impact of the upper limb function of the affected side on self-care in individuals with stroke remains highly controversial. Some previous studies have shown that the degree of upper limb function and the ability to perform self-care tasks are strongly related.[27,28] On the contrary, other studies have reported that the degree of upper limb function of the affected side and self-care independence are not related[29] or the impact of upper limb function impairments on everyday activities may be less than expected.[12] Michielsen et al.[30] pointed out that before the performance of the upper limbs of the affected side starts to increase in actual daily life, a certain threshold level of upper limb functioning on the paretic side must be reached, and the results of the present study supports this. We also found that upper limb function on the affected side is particularly important for patients with impaired balance. One reason for this is because if balance is significantly unstable, the upper limbs of the unaffected side might not be used well enough, and thus, the involvement of upper limbs on the affected side in everyday activities is required. Another reason is that patients with impaired balance need to compensate balance by using the affected hand to hold a support. On the contrary, if the balance function is high, the upper limbs of the unaffected side can be effectively used and high level of functioning is not required for the upper limbs of the affected side.

We believe that the decision tree and existence of the interaction between the balance and the upper limb function of the affected side presented in this study could serve as an effective guide when implementing a remedial approach for individuals with stroke aiming to achieve self-care independence. The results of this study strongly indicate that the 2 overlapping conditions of low balance and low upper limb function of the affected side significantly reduce the probability of self-care independence. According to the decision tree created, in cases where patients are incapable of independent self-care, balance training aimed at achieving a BBS score of 41 points should be performed first. Previous studies have reported that BBS scores of 0-20 represent balance impairment, 21-40 represent acceptable balance, and 41-56 represent good balance.[31] The results of this study indicated the possibility of self-care independence greatly changes depending on whether or not it reaches a BBS score of 41 points. In patients with considerably impaired balance or those in whom improved balance is not expected, as the next step, rehabilitation of the upper limb function on the affected side aimed at achieving a STEF score of 80 points may be effective for independence in self-care. However, because a STEF score of 80 points is a relatively high functioning level, it is important for the therapist to judge which balance and upper limb function is more realistic to reach the cutoff value.

This study has several limitations. First, it is based on data from one point in time during the hospital stay, and there was some variation in the time since onset among the patients. We cannot rule out the possibility that numerous factors involved in self-care independence might change over time, independent of any treatment or therapies, and therefore, further chronological analysis is needed. Second, the subject sample entirely consisted of inpatients. Therefore, it is unclear whether our results can be generalized to patients in much different environments, such as community-dwelling individuals with stroke. Third, we cannot say that the sample size was sufficient. Increasing the sample size used in future investigations might enable more detailed comparisons with the present results, such as which factors are most involved in determining self-care independence or dependence in the group with BBS scores of more than 41 points.

Conflict of Interest

There are no conflicts of interest to declare.

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