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Original Article

Identification of the affected lower limb and unaffected side motor functions as determinants of activities of daily living performance in stroke patients using partial correlation analysis

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Abstract. [Purpose] This study aimed to clarify the independent impact of the affected upper and lower limb, trunk, and unaffected side motor functions on activities of daily living in stroke patients using partial correlation analysis. [Subjects and Methods] This retrospective study included 77 stroke patients. Motor functions were assessed using the Stroke Impairment Assessment Set, and the activities of daily living performance was assessed using the Barthel index or Functional Independence Measure. Further, simple and partial correlation analyses were conducted between each motor function and activities of daily living parameter. [Results] Simple correlation analysis identified significant positive correlations for each pair. In contrast, partial correlation analysis only identified significant positive correlations between the affected lower limb or unaffected side functions and the Barthel index or Functional Independence Measure. This discrepancy between the two tests was explained by the significant interaction between the affected upper and lower limb functions and between the trunk and unaffected side functions. [Conclusion] The present study identified the affected lower limb and unaffected side motor functions as the major determinants of activities of daily living performance in stroke patients. These findings suggest that rehabilitation programs can be improved by targeting these areas.
Key words: Stroke, Activities of daily living, Motor function

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INTRODUCTION

Motor and cognitive impairments in stroke patients dramatically reduce their independence in activities of daily living (ADL). In particular, the physical symptoms of stroke have a greater effect on the patients' independence than the cognitive component[1)]. Therefore, understanding the relationship between motor function and ADL is important to design efficient rehabilitation programs aimed at improving ADL performance.

This ability to perform ADL is influenced by motor functions of the upper and lower limbs[2, 3)] and the trunk[4–6)]. Likhi et al.[7)] reported that ADL performance in stroke patients correlated more closely with the impairment level of the trunk than that of the upper limb, whereas lower limb impairment showed no correlation with ADL. However, Fong et al.[8)] reported that lower limb impairment correlated more closely with ADL than upper limb impairment. In contrast, Ezure et al.[9)] reported that the upper limb, lower limb, and trunk functions were significantly correlated with ADL. Multiple linear regression analysis revealed that trunk function exhibited a stronger relationship with ADL than the affected side function. Therefore, the impact of limb and trunk function impairment on ADL in stroke patients remains highly controversial.

Most stroke patients develop comparable motor impairment in the upper and lower limbs[10)]. This is consistent with the well-known strong association between motor functions of the affected upper and lower limbs. Therefore, correlation analysis must be designed to avoid bias. For instance, a correlation analysis between the affected upper limb function and ADL must be conducted in the absence of the effect of the affected lower limb function on ADL. To the best of our knowledge, no study has conducted partial correlation analyses between limb or trunk function impairment and ADL in stroke patients. Therefore, the present study aimed to investigate the independent influence of the affected upper and lower limb, trunk, and unaffected side function on ADL

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Table 1. Stroke-related characteristics of study subjects

	Mean±SD	Range
Age, years	68.5±12.7	36–93
Time post-stroke, days	84.8±37.4	37–236
Males, %	69.2	
Right-sided hemiparesis, %	48.8	
Affected upper limb function (0–10)	6.4±3.0	0–10
Affected lower limb function (0–15)	11.7±3.8	1–15
Trunk function (0–6)	5.3±1.0	0–6
Unaffected side function (0–6)	5.3±0.9	2–6
Barthel Index (0–100)	86.8±17.7	5–100
Motor item of FIM (13–91)	73.3±16.0	22–91

FIM: Functional Independence Measure

Table 2. Simple and partial correlation analyses between motor functions and indexes of activities of daily living (FIM and BI) in stroke patients

	Simple Correlation (N=77)		Partial Correlation (N=77)	
	FIM	BI	FIM	BI
Affected upper limb function	0.31**	0.34**	0.02	0.07
Affected lower limb function	0.51**	0.51**	0.48**	0.42**
Trunk function	0.37**	0.33**	0.15	0.13
Unaffected side function	0.38**	0.34**	0.32**	0.27*

Values are Spearman's rank coefficients; **p≤0.01
FIM: Functional Independence Measure; BI: Barthel Index

using partial correlation analysis.

SUBJECTS AND METHODS

This study was a retrospective secondary analysis of a database. The study cohort included 77 stroke patients (53 males and 24 females) who were admitted to the Northern Fukushima Medical Center between October 2010 and November 2013. They fulfilled the following inclusion criteria: first stroke; unilateral supratentorial hemispheric lesion; absence of marked cognitive deterioration [≥5 cognitive items of the Functional Independence Measure (FIM)[11], described below]; and unilateral spatial neglect based on the Stroke Impairment Assessment Set[12] (SIAS; described below). The mean patient age was 68.5 years, and the mean time from stroke onset was 84.8 days. Subject characteristics are listed in Table 1. The study protocol was approved by the institutional ethics review board of Northern Fukushima Medical Center (Fukushima, Japan).

We compiled data on motor function, trunk function, and unaffected side function from the SIAS, Barthel Index (BI)[13], and FIM evaluations. The SIAS test (0–5) items evaluate motor function of the affected limb (knee-mouth, finger function, hip flexion, knee extension, and foot-pat tests), the trunk (abdominal muscle strength and verticality), and the unaffected side (strength of knee extension and grip strength). Details on the method, reliability, and validity of SIAS have been reported elsewhere[12, 14–16]. In addition, the independence index of ADL was determined using the BI and motor items of the FIM scoring system.

In the present study, the affected upper limb function was calculated from the total score of the knee-mouth and finger function tests. Lower limb function was calculated from the total score of the hip flexion, knee extension, and foot-pat tests. Furthermore, trunk function was calculated from the total score of the abdominal muscle strength and verticality tests, and the unaffected side function was calculated from the total score of grip strength and knee extension strength tests. We used simple correlation and partial correlation analyses to remove the effect of age and other motor function parameters (affected upper limb, lower limb, trunk, and unaffected side function), and estimated the independent effect of the affected upper limb, lower limb, trunk, and unaffected side functions on BI or FIM. All correlations were investigated using Spearman's rank correlation analysis with SPSS version 22.0 for Windows; p values <0.05 were considered statistically significant.

RESULTS

It was observed that half of the patients (48.8%) had right-sided hemiparesis, with mild to moderate impairment of the upper and lower limbs. Simple and partial correlation analyses were conducted between the parameters of motor function (affected upper limb, lower limb, trunk, and unaffected side function) and ADL (BI or FIM scores) (Table 2). Moreover, simple correlation analyses revealed significant positive correlations for all comparisons. Partial correlation analyses generated remarkably different data when the effect of age and other body part functions on ADL were excluded. Significant positive correlations were found between the affected lower limb or unaffected side function and BI or FIM. In contrast, there was no significant correlation between the affected upper limb or trunk function and BI or FIM. This discrepancy is explained by the strong functional interactions between the affected upper limb and lower limb functions and between the trunk and unaffected side functions (Table 3).

DISCUSSION

The present study provides insightful information on the relationship between motor function and ADL in stroke patients. The ongoing debate on motor functions affecting ADL was resolved by designing partial correlation analysis protocols considering the possible interactions between body parts. Simple correlation analysis suggested that the affected upper limb, lower limb, unaffected limbs, and trunk influence ADL performance. In contrast, partial correlation analysis, excluding age and the influence of other body parts, revealed the absence of correlation between the affected upper limb or trunk function and ADL in stroke patients. This discrepancy was explained by the strong interactions between the affected upper and lower limb functions and between trunk and unaffected side functions. This new information on motion dynamics in stroke patients should lead to the development of more efficient rehabilitation programs.

Table 3. Simple correlation analyses between motor functions in stroke patients

	Affected U/L function	Affected L/L function	Trunk function	Unaffected side function
Affected U/L function		0.68**	−0.01	−0.08
Affected L/L function	0.68**		0.14	−0.03
Trunk function	−0.01	0.14		0.39**
Unaffected side function	−0.08	−0.03	0.39**	

Values are Spearman's rank coefficients; **p≤0.01
FIM: Functional Independence Measure; BI: Barthel Index; U/L: Upper Limb; L/L: Lower Limb

This study demonstrates that ADL performance in stroke subjects is hindered more by the affected lower limb than by the unaffected side. Previous studies reported that balance[2], gait[17, 18], and stair[19] performance are affected by lower limb function. Thrane et al.[20] reported that the affected lower limb function is associated with self-care dependency. Further, the present study also indicates that the affected lower limb function plays an important role in ADL.

We established a considerable relationship between the unaffected side function and ADL, based on the strength of the quadriceps muscle of the lower limb and the grip strength. It has been reported that the strength of quadriceps muscle influences sit-to-stand[21] and transfer[22] activities in stroke subjects. In addition, several studies found an association between grip strength and ADL[23]. Colebatch et al.[24] indicated that the strength of muscles ipsilateral to the lesion was reduced in hemiplegic patients compared with healthy subjects. Therefore, rehabilitation programs aiming to improve ADL should target the muscle strength on the unaffected side.

The lack of correlation between the affected upper limb function and ADL may be explained by the fact that most activities can be performed with the unaffected upper limb. Further, previous studies mentioned that the upper limb function is required to reach a certain threshold before performance actually starts to increase[25], and improvement in the functional limitations of the upper limb does not necessarily lead to a full recovery of ADL function[26]. Therefore, there may be a non-linear relationship between the affected upper limb function and ADL. Thrane et al.[20] reported no significant relationship between the affected upper limb impairments and ADL using lower limb function as covariate, as in our study. Thus, the impact of upper limb function impairments on everyday activities may be lower than expected[27].

The close relationship between trunk function and ADL has been reported by previous studies[4–7, 9]. However, to the best of our knowledge, this is the first study to identify the independent effect of trunk function on ADL using partial correlation analysis. In addition, our results suggest that the impact of trunk function on ADL is lower than expected. However, the average score of trunk function in our patients was very high, suggesting that a relationship between trunk function and ADL could have been missed due to the ceiling effect. Therefore, this result should be carefully interpreted.

There are several limitations to our study. First, simple and partial correlation analyses can only detect linear relationships between two variables. Therefore, the existence of non-linear relationships could not be addressed. Second, the index of ADL independence was relatively high in our subject group. The correlations between each motor function and ADL may differ depending on the ADL independence level. As such, different results may be obtained for severe stroke patients.

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