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Original Article

Interaction between locomotion and three subcategories for patients with stroke demonstrating fewer than 37 points on the total functional independence measure upon admission to the recovery ward

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Abstract. [Purpose] To investigate the interaction between locomotion and improvements in performing self-care. [Participants and Methods] We retrospectively analyzed 930 patients with stroke who were registered in the Japanese Rehabilitation Database. We performed a correlation analysis to evaluate the relationships among all the collected data. Then, hierarchical multiple regression analysis was performed using the self-care motor score of the Functional Independent Measure (FIM) as the dependent variable. "Model 1" used two independent variables (National Institute of Health Stroke and Rankin Scale), "model 2" used two independent variables (locomotion gain and gain of an item with the closest coefficient correlation added to model 1), and "model 3" used a mean-centering value, which was added to model 2. R^2 values were calculated using a simple slope analysis. [Results] Locomotion showed an interaction with three self-care activities. The R^2 changes in models 1 and 2 (ΔR^2) were significant for dressing upper body (ΔR^2=0.001), bowel management (ΔR^2=0.006), and toileting (ΔR^2=0.006). The results of the simple slope analysis were significant. [Conclusion] Locomotion demonstrated an interaction with various activities for improving self-care. There were varying degrees of improvement in self-care despite a uniform improvement in the degree of locomotion. Therefore, locomotion interaction should be considered for each intervention that targets activities of daily living.

Key words: Stroke, Interaction, Gait

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INTRODUCTION

Patients with stroke have particular functional disabilities that may cause locomotion reduction and, subsequently, affect their activities of daily living (ADLs)[1–3)]. However, it has been reported that improvements in ADL and locomotion are necessary for social reintegration[4)]. Thus, in the early stages of stroke rehabilitation, interventions focus on achieving locomotion. There is a significant correlation between locomotion and ADLs; locomotion improvement may positively affect ADL performance[1, 5, 6)]. Locomotion that has deep relation with ADLs involves standing, balance, paretic lower limb strength, and trunk functions, which influence and can predict ADL improvement. Additionally, it has been reported that gait-training exercises influence ADL performance in the early post-stroke period[1–3, 6)]. Therefore, locomotion is addressed early in stroke rehabilitation despite the difficulties in ADL performance. However, these have been reported based on the

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significance between exercise and ADL, which were mainly from the main effect of the correlation viewpoint.

Previous reports have shown that locomotion is correlated with the motor-Functional Independence Measure (m-FIM) score[7–9]. Patients with stroke who have a higher locomotion ability may have higher m-FIM scores and be able to perform ADLs better, thus preventing ADL decline. As ADLs are necessary for many functions of the body, motor and sensory paralysis, balance disability, and non-affected functions, such as age and cognitive function, may affect ADL improvement. Trunk function is reportedly the most significant parameter required for performing ADLs, and it influences motor and balance functions (e.g., sitting and standing balance)[3, 5, 10]. Motor and trunk functions may be correlated with locomotion. These results show the relevance and contribution of locomotion to ADLs[3, 11]. However, these results do not provide information regarding the role of each action in rehabilitation. Previous studies also have reported the influence of cognitive tasks on locomotion[12, 13]. These results also have been in accordance with the main effect of correlation. Despite the vast amount of literature available on the relationship between locomotion and self-care, the interaction between increased locomotion performance and improvements in independently performed ADLs other than locomotion is not elucidated enough in stroke patients upon admission in recovery ward. Moreover, it has reported that interaction impact has an influence on the main effect.

Therefore, it is important to clarify whether there is an interaction between locomotion and improved ADL performance. This could be beneficial for improving ADL performance through gait training during the rehabilitation of patients with stroke. Thus, this study's objective was the assessment of the interaction between locomotion and improvement in the performance of self-care activities based on the m-FIM score.

PARTICIPANTS AND METHODS

The medical data of 6,875 patients with stroke were extracted from the stroke/recovery rehabilitation phase ward (January 2016 version) from the Japan Rehabilitation Database (JRD). We used anonymized observational data obtained in normal clinical settings. The need for informed consent was waived due to the retrospective, observational design of the study, and the use of secondary data. The original data collection had been approved by the Ethics Committee of the Japanese Association of Rehabilitation Medicine. However, the committee did not issue an approval number. The inclusion criteria were as follows: age, 15–99 years; days from onset to admission, 5–90; days of ward stay, 21–210; total FIM score at admission, <37; gain (the difference between each m-FIM item score at discharge and admission), >0. All data were collected, and finally, data from 930 cases were analyzed. The state of these data is classified as the severe group according to the FIM score. Motor FIM scores at admission and discharge were the primary outcome measures. Information based on the National Institute of Health Stroke Scale (NIHSS) and Rankin scale (RS) was also collected. The FIM score is reported to have high reliability and validity concerning the ADL evaluation after stroke; it consists of 13 m-FIM and 5 cognitive FIM (c-FIM) items[14, 15]. The m-FIM comprises 13 items in 4 subscales: Self-care, Sphincter control, Transfers, and Locomotion. Self-care includes the activities of Eating, Grooming, Bathing, Dressing (upper [U/B] and lower body [L/B]), Toileting, Sphincter control (Bladder and Bowel management), Transfers (Transferring to bed, chair, wheelchair/ toilet/ and tub/shower), Locomotion (Walk or Wheelchair, and Stairs). All items were scored using a 7-point ordinal scale: level 1, Total Assist; level 2, Maximal Assist; level 3, Moderate Assist; level 4, Minimal Assist; level 5, Supervision; level 6, Modified Independence; and level 7, Complete Independence. Gender differences were not significant, and reports on such differences are limited[16, 17]. The stroke type does not generally influence the prognosis[18, 19]. Therefore, this information was excluded from this study. Age, duration from onset to hospital admission, length of ward stay, cognitive FIM score, and NIHSS and RS scores at admission were set as the general items. First, correlation analyses were performed using all data. Then, the evaluation of locomotion interaction was performed using hierarchical multiple regression. The NIHSS and RS scores were set as the control variables. This analysis used the m-FIM gain of self-care as the dependent variable, a prediction formula (model 1) using two items as independent variables (NIHSS, RS) to evaluate the correlation of the control variables. Model 2 added two items as the independent variables (gain of locomotion [locomotion-g] and gain of an item with the closest correlation coefficient to all items [Spearman's rank correlation]). Interaction was defined to occur when the effect of an independent variable on a dependent variable varied across the levels of a moderating variable. Locomotion gain (the difference between the Locomotion item score at discharge and admission) was set as the moderator value in this study[20, 21]. Then, a prediction formula, namely "model 3", added a mean-centering value to model 2. The mean-centering value was calculated by multiplying each value by subtracting the mean from the raw value. Finally, a simple slope analysis was performed as a subtest to assess locomotion interaction. The interaction is a kind of impact that occurs when two or more factors affect each other. It has been defined that the idea of a two-way effect is essential in the concept of interaction, as opposed to a one-way causal effect. The statistical significance level was set at $p<0.05$. All statistical analyses were conducted using IBM SPSS version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The baseline characteristics of the patients used in this study are shown in Table 1. Table 2 details correlations among all items and the correlation coefficient of locomotion-g to self-care activity performance was stronger than that for the general

Table 1. Characteristics of extraced data sample (n=930)

Descriptive characteristic	Value
Age (years)	72.74 ± 11.87
Days from onset to admission	37.76 ± 14.96
Days of ward stay	121.26 ± 40.4
m-FIM at admission	21.56 ± 7.24
c-FIM at admission	12.14 ± 6.15
NIHSS at admission	2.41 ± 4.03
RS at admission	4.23 ± 0.85
Eating gain	1.68 ± 1.63
Grooming gain	2.02 ± 1.78
Bathing gain	1.55 ± 1.61
Dressing Upper Body gain	2.27 ± 1.94
Dressing Lower Body gain	2.11 ± 2.03
Toileting gain	2.43 ± 2.06
Bladder management gain	2.13 ± 12.1
Bowel management gain	2.18 ± 1.99
Transfer Bed/Weelchair	2.34 ± 1.53
Tranfer Toilet	2.45 ± 1.71
Transfer Bath/Shower	1.61 ± 1.6
Locomotion gain	2.34 ± 2.01
Stairs gain	1.69 ± 1.08

Values are presented as mean ± standard deviation.
m-FIM: motor Functional Independence Measure; c-FIM: cognitive Functional Independence Measure; gain: the difference between each motor FIM at discharge and admission; NIHSS: Natinal Institute of Health Storke Scale; RS: Rankin scale.

item and similar for NIHSS and RS. Table 3 exhibits the hierarchical multiple regression analysis results as follows: Dressing U/B (ΔR^2=0.001, p<0.05), Bowel management (ΔR^2=0.006, p<0.01), and Toileting (ΔR^2=0.006, p<0.01).

Table 4 presents the effect of the independent to the dependent variables as moderated by locomotion-g in any case. The study's flow diagram is presented in Fig. 1.

DISCUSSION

This study found that locomotion interaction affected the performance of the following ADLs: Dressing U/B, Toileting, and Bowel management in patients with stroke who had a total FIM score <37 points at admission. It was shown that there were varying degrees of improvement in self-care despite a uniform improvement in the degree of locomotion. The importance of this retrospective study lay in the examination of locomotion interaction with individual self-care activities in patients with stroke using multi-facility data. The importance of this retrospective study lay in the examination of locomotion interaction with individual self-care activities in patients with stroke using multi-facility data.

The severe group was targeted in this study. Recovery processes of m-FIM have been reported to sharply increase by rehabilitation intervention in the recovery ward for stroke. Moreover, it has been reported that gait training is mainly effective for the severe state. However, this strategy is according to the main effect of the correlation viewpoint. Therefore, it was assumed that the severe group was targeted to investigate locomotion interaction.

Previous reports have shown a correlation between ADL performance and gait in patients with stroke[4, 5)]. Moreover, gait training has been suggested to be important[6–8)]. The function of the affected side, lower extremity muscles, and balance are the major determinants of ambulation after stroke[2, 10)]. Recent gait-training strategies highlighted a relationship between the passenger and locomotion units and mentioned the importance of trunk function[2, 22)].

The trunk has long been defined as a so-called passenger unit owing to its significant role in gait[23)]. Thus, the collaboration of passenger and locomotion units is required for optimizing gait in patients with stroke[23, 24)]. The impaired passenger unit was reported to cause a decreased gait. Additionally, the asymmetric motion of the trunk between the affected and unaffected sides affect gait[3)]. Therefore, it is considered that trunk function increases with improving gait.

The contraction of the contralateral muscles in the trunk begins at the early stage. Further, shifting the gravity center to the foot on one side in gait also initiates a contraction of the abdominal oblique muscle. Improved gait influences collaboration between the passenger and locomotion units. For this reason, trunk function is increased by improved gait.

Table 2. Correlation among all items

	Eating gain	Grooming gain	Bathing gain	Dressing Upper Boddy gain	Dressing Lower Boddy gain	Toileting gain	Bowel management gain	Bladder management gain	Transfer/ Bed gain	Transfer/ shower gain	Transfer/ toilet gain	Locomotion gain	Stairs gain	General item: Age	General item: Days from onset to admission	General item: Days of ward stay	General item: c-FIM at admission	RS at admission	NIHSS at admission
Eating gain	1.00	0.441**	0.255**	0.260**	0.233**	0.227**	0.215**	0.242**	0.282**	0.201**	0.255**	0.154**	0.142**	−0.083*	−0.040	0.115**	−0.073*	0.058	0.047
Grooming gain		1.00	0.603**	0.651**	0.632**	0.607**	0.505**	0.516**	0.524**	0.495**	0.550**	0.499**	0.360**	−0.219**	−0.140**	0.062	0.219**	−0.198**	−0.098**
Bathing gain			1.00	0.737**	0.748**	0.744**	0.588**	0.539**	0.557**	0.737**	0.607**	0.589**	0.496**	−0.278**	−0.134**	0.033	0.311**	−0.255**	−0.107**
Dressing Uppr Boddy gain				1.00	0.905**	0.749**	0.625**	0.577**	0.614**	0.637**	0.641**	0.611**	0.482**	−0.263**	−0.13**	0.073*	0.317**	−0.273**	−0.162**
Dressing Lower Boddy gain					1.00	0.799**	0.633**	0.580**	0.604**	0.661**	0.639**	0.607**	0.516**	−0.254**	−0.132**	0.021	0.328**	−0.301**	−0.153**
Toilting gain						1.00	0.700**	0.648**	0.670**	0.692**	0.738**	0.621**	0.540**	−0.268**	−0.161**	0.056	0.342**	−0.231**	−0.163**
Bowel management gain							1.00	0.788**	0.528**	0.541**	0.575**	0.543**	0.452**	−0.300**	−0.111**	0.102**	0.333**	−0.106**	−0.121**
Bladder management gain								1.00	0.528**	0.494**	0.565**	0.506**	0.400**	−0.249**	−0.107**	0.097**	0.263**	−0.154**	−0.138**
Transfer Bed gain									1.00	0.546**	0.859**	0.579**	0.360**	−0.244**	−0.186**	0.157**	0.274**	−0.220**	−0.123**
Transfer shower gain										1.00	0.614**	0.535**	0.516**	−0.232**	−0.161**	0.010	0.252**	−0.201**	−0.121**
Transfer toilet gain											1.00	0.593**	0.400**	−0.237**	−0.162**	0.112**	0.294**	−0.217**	−0.130**
Locomotion gain												1.00	0.433**	−0.345**	−0.161**	0.123**	0.274**	−0.179**	−0.157**
Stairs gain													1.00	−0.287**	−0.085**	0.025	0.193**	−0.075*	−0.165**
Age														1.00	−0.056	−0.183**	−0.070*	−0.024	0.059
Days from onset to admission															1.00	0.097**	−0.146**	0.148**	0.014
Days of ward stay																1.00	0.093**	0.143**	0.020
c-FIM at admission																	1.00	−0.188**	−0.368**
RS at admission																		1.00	0.237**
NIHSS at admission																			1.00

Gain: the difference between each motor FIM at discharge and admission; c-FIM: cognitive Functional Impairment Measure; RS: Rankin scale; NIHSS: National Institute of Health Stroke Scale.
*p<0.05, **p<0.01.

Table 3. The resulus of hierarchical multiple regression analysis

a) Dressing Upper Body gain

Variable	Step 1		Step 2		Step 3	
	b	b SE	b	b SE	b	b SE
Step 1						
NIHSS	−0.01	0.02	−0.004	0.01	−0.004	0.01
RS	−0.57***	0.07	0.01	0.03	0.02	0.03
Step 2						
Dressing Lower Body gain			0.83***	0.02	0.83***	0.02
Locomotion gain			0.09***	0.02	0.09***	0.02
Step 3						
Dressing Lower Body gain × Locomotion gain					−0.02*	0.01
ΔR^2			0.779		0.001	
Adj R^2			0.844		0.845	

b) Toileting gain

Variable	Step 1		Step 2		Step 3	
	b	b SE	b	b SE	b	b SE
Step 1						
NIHSS	−0.01	0.02	−0.004	0.01	−0.004	0.01
RS	−0.51***	0.08	0.02	0.05	0.04	0.05
Step 2						
Dressing Lower Body gain			0.68***	0.03	0.7***	0.03
Locomotion gain			0.23***	0.02	0.23***	0.24
Step 3						
Dressing Lower Body gain × Locomotion gain					−0.04***	0.01
ΔR^2			0.620		0.006	
Adj R^2			0.668		0.673	

c) Bladder management gain

Variable	Step 1		Step 2		Step 3	
	b	b SE	b	b SE	b	b SE
Step 1						
NIHSS	−0.01	0.02	0.69	0.02	0.71	0.24
RS	−0.57***	0.07	0.10**	0.02	0.10	0.24
Step 2						
Bowel management gain			0.69***	0.02	0.71***	0.24
Locomotion gain			0.10***	0.02	0.10***	0.24
Step 3						
Bowel management gain × Locomotion gain					−0.04***	0.01
ΔR^2			0.008		0.006	
Adj R^2			0.619		0.625	

Gain: the difference between each motor FIM at discharge and admission; NIHSS: National Institute of Health Stroke Scale at admission; RS: Rankin scale at admission.
*p<0.05, **p<0.01, ***p<0.001.

The trunk has an important function in the ADLs that was shown to be significant in this study. In dressing-like activities, it is necessary to start sitting and gradually develop the movements[25, 26]. A static sitting balance is required for active trunk extension and forwards pelvic tilt[26, 27]. To position the trunk forward of the pelvis when sitting, the abdominal, internal oblique muscles, and musculus multifidus lumborum in the trunk are important as are the iliopsoas muscle[25] and gluteus maximus muscles. Moreover, movements of the center of gravity in all directions (forward/backward, lateral flexion, and rotation in both sides) are required in performing dressing[25, 26]. Motor function, especially balance, has a more significant

Table 4. Simple slope model of extracted item

a) Dressing Upper Body gain

	b	b SE
Locomotion gain low		
Intercept	0.37	0.04
Dressing Lower Body gain	0.86***	0.02
Locomotion gain		
Intercept	0.55	0.04
Dressing Lower Body gain	0.83***	0.02
Locomotion gain high		
Intercept	0.74	0.07
Dressing Lower Body gain	0.80***	0.02

b) Toileting gain

	b	b SE
Locomotion gain low		
Intercept	0.61	0.06
Dressing Lower Body gain	0.78***	0.03
Locomotion gain		
Intercept	1.07	0.06
Dressing Lower Body gain	0.70***	0.02
Locomotion gain high		
Intercept	1.53	0.10
Dressing Lower Body gain	0.61***	0.03

c) Bladder management gain

	b	b SE
Locomotion gain low		
Intercept	0.55	0.07
Bowel management gain	0.74***	0.03
Locomotion gain		
Intercept	0.78	0.07
Bowel management gain	0.69***	0.02
Locomotion gain high		
Intercept	1.00	0.10
Bowel management gain	0.63***	0.03

Moderator variable, Locomotion gain. Locomotion gain low: mean-1SD; Locomotion gain high: mean + SD; gain, the difference between each motor FIM at discharge and admission.
***p<0.001.

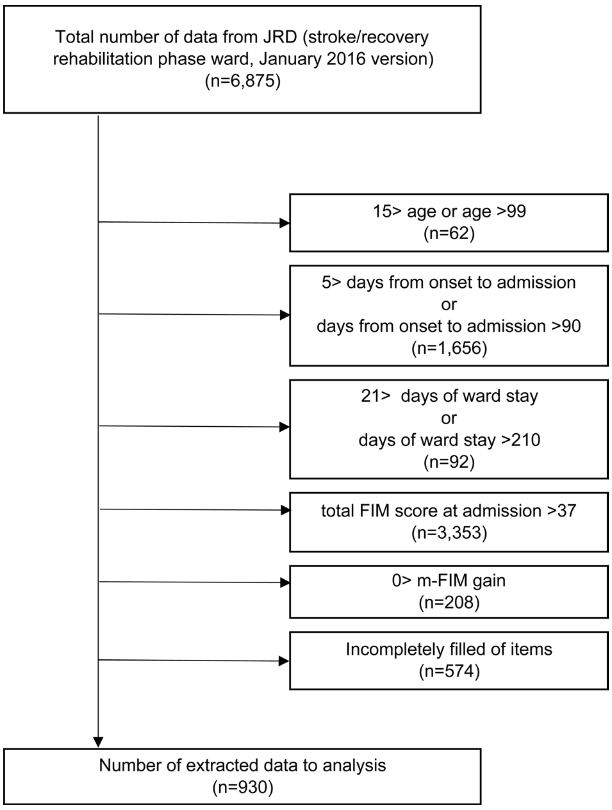

Fig. 1. Flowchart of the data sampling with reason for exclusion. JRD: Japanese Rehabilitation Database; FIM: Functional Independence Measure; gain: the difference between each motor FIM at discharge and admission.

impact on dressing independence than cognitive function[29, 30].

Toileting consists of three major actions; manipulating lower garments, cutting paper, and transferring to a toilet[31]. In patients with stroke, toileting has been usually proposed to be performed in a sitting position to avoid any possible down-turn[32, 33]. The first two actions are performed with one hand. Trunk balance and upper limb function are required for roll sitting[29, 33]. However, it has been reported that the affected upper limb does not contribute to toileting independence because the patient has learnt to perform toileting by using the unaffected hand only[29, 33]. Therefore, trunk function is related to balance in toileting and is important for the affected upper limb[34]. It was reported that TrA function influences the unaffected upper limb use with excretion[31, 34]. Moreover, a past report stated that grip strength for handling lower body garments was improved by trunk function[31].

Hence, it is considered that trunk function increases with improving gait, and Dressing U/B, Toileting was more easily influenced as locomotion interaction indirectly affected it.

Urinary incontinence (UI) that is a common issue in patients with stroke, is one of the symptoms caused by an overactive bladder and is observed in the recovery phase[35]. The sphincter muscle is also important for bladder and bowel management. The pelvic floor muscle (PFM) is associated with sphincter and supports the abdominal viscera from the pelvic floor[32, 36]. The passenger unit during post-stroke gait consists of the PFM, TrA, multifidus muscle, and the diaphragm. PFM contractions appear during urination, and increased abdominal pressure occurs with trunk muscle group co-contraction, e.g., the transversus abdominis, multifidus muscle, and diaphragm. Similarly, PFM affects defecation. These muscles work for contraction by increasing intra-trunk pressure and impact bowel management and gait performance in combination with global muscles. For that reason, it was considered that bowel management was influenced by locomotion interaction.

However, the results of this study showed locomotion interaction only with bowel management. Abdominal pressure is higher in defecation than in detrusor activities. Likewise, contraction in the lower trunk direction is necessary for defecation. Moreover, previous reports have also stated that TrA contraction dysfunction may affect defecation[32, 33, 35]. Therefore, it was thought that locomotion interaction affected defecation rather than the detrusor muscles.

However, the results of this study showed no significance in impacting locomotion interaction with other ADLs. These results were considered as follows: Activities of Eating were less than performing dressing that movements close to the center of gravity are required all directions[28], Dressing L/B-like activities tend to leave from the backrest. Moreover, bowel management-like activities need higher pressure than bladder management and are more difficult. Therefore, the trunk impact might not have much influence on activities like that.

A limitation of this study is that the participants were only patients with stroke who had a total m-FIM score <37 points at admission, and therefore, locomotion interaction in patients who have a higher m-FIM score should be determined in a future study.

In conclusion, locomotion showed an interaction with post-stroke self-care in patients with an m-FIM score <37-point at admission, according to the JRD. Self-care activities that were affected by locomotion interaction were Eating, Dressing U/B, Bowel management, and Toileting. Locomotion interaction was not shown in all ADLs. Therefore, this study's findings suggest that locomotion interaction results in varying degrees of improvement in ADLs and, therefore, should be considered in the development of each intervention targeted at ADLs.

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Conflict of interest

The authors declare that they have no potential conflict of interest relevant to this article to declare.

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