The Association between Total Energy Expenditure and Cognitive Function in Convalescent Patients with Cerebrovascular Disease*

Maki Kojima\(^1,2\) and Akinori Nagano\(^3\)

\(^1\)Department of Rehabilitation Medicine, Nishiyamato Rehabilitation Hospital
3-2-2 Sasayuri-dai, Kanmaki-cho, Kitakatsuragi-gun, Nara 639-0218, Japan
makiyama.sun@gmail.com

\(^2\)Graduate School of Sport and Health Science, Ritsumeikan University
1-1-1 Norohigashi, Kusatsu-shi, Siga 525-8577, Japan

\(^3\)Faculty of Sport and Health Science, Ritsumeikan University
1-1-1 Norohigashi, Kusatsu-shi, Siga 525-8577, Japan

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**Objective** It has been reported that everyday physical activity, exercise, and physical fitness in older adults can affect their cognitive function. However, to our knowledge, no empirical evidence of this effect has yet been reported in convalescent patients with cognitive impairment resulting from cerebrovascular disease. Therefore, for such patients, it is important to investigate this issue to ensure optimal amelioration of their cognitive impairment during rehabilitation. The aim of this study was to estimate the amount of total energy expenditure during hospitalization, and to investigate the association between total energy expenditure and cognitive function in convalescent patients with cerebrovascular disease.

**Methods** We recruited 24 patients (16 men and 8 women; average age \(68.8 \pm 10.6\) years) with cerebrovascular disorders. The total energy expenditure of each subject per day was estimated by the factorial method for five months. Cognitive function was assessed using items on the Functional Independence Measure (FIM).

**Results** Both total energy expenditure and cognitive items on the FIM increased significantly \((p < 0.001)\) during the five-month period. A significant correlation was found between them \((r = 0.294, p = 0.001)\), and the two showed a significant partial correlation \((r = 0.221, p = 0.016)\) when weight was used as a control variable. There was also a significant partial correlation between the gain in total energy expenditure and the gain in the cognitive items on the FIM when the baseline score for cognitive function was used as a control variable \(3\) months: \(r = 0.466, p = 0.044; 5\) months: \(r = 0.485, p = 0.035\).

**Discussion** We conclude that there is a relationship between total energy expenditure and cognitive function in convalescent patients with cerebrovascular disease.

**Keywords:** physical activity, factorial method, cognition, rehabilitation, functional independence measure

1. Introduction

Stroke is the fourth most common cause of mortality in Japan. It is reported that about 1.1 million people die of stroke every year, while about 1.5 million people suffer a stroke annually (Ministry of Health, Labor and Welfare, Statistical Information Division Demographics, and Health Statistics Division Demographics Dynamics Statistics Annual Report, online September 3, 2015). Moreover, due to the aging of Japanese society, stroke has become the disease that accounts for the highest number of patients certified for care under the long-term care insurance scheme (Ministry of Health, Labor and Welfare, Statistical Information Division, Social Statistics Division, National Life Basic Research Office Overview of the 2010 National Life Basic Survey, online July 12, 2011). Stroke (i.e., cerebral...
hemorrhage or cerebral infarction) damages cerebral tissue, resulting in various neurological symptoms and impairment of motor and cognitive function (Maeshima, 2003). Cognitive decline resulting from higher brain dysfunction, including aphasia, unilateral spatial neglect, attention deficit, and memory loss, is particularly common in stroke patients. To minimize these deleterious effects, rehabilitation is started in the acute phase after onset. Subsequently, once the patient’s general condition is stable, positive rehabilitation is started in the convalescent phase, and special assessments and intensive training programs are initiated. At this stage, significant recovery of cognitive function lost due to brain damage is anticipated. In a previous study (Desmond et al., 1996), researchers found that recovery of cognitive function was greatest in the three months after stroke onset. Although long-term recovery is affected by the size and site of the lesion, it has been reported that effective rehabilitation should be initiated as soon as possible. Therefore, patients should receive appropriate rehabilitation at the earliest possible stage. However, rehabilitation can often be difficult due to various factors such as the mental state of the patient, whether the assistance provided is appropriate, and the type of intervention provided at the time of admission. In addition, in the Japanese system, the period of hospitalization for convalescence and interventions for recovery of cognitive function is limited to 180 days, after which patients are shifted from rehabilitation to long-term care. Therefore, some patients may not be able to receive sufficient rehabilitation. To ensure that rehabilitation is sufficient, it is necessary to adjust conditions such as medical care, medical staff, and full rehabilitation planning.

In recent years, it has been reported that there is an association between physical activity, exercise, and cognitive function. For example, physical activity has been found to inhibit the progression of dementia (Aarsland et al., 2010), and brain functions, especially attention, memory, and executive function, are reportedly improved by aerobic exercise (Smith et al., 2010). Executive function is considered to be necessary for achieving a series of objective activities. This includes elements such as setting targets, setting action plans, and effectively performing the necessary actions (Muramatsu et al., 2008). Another study has found that the trend of cognitive function decline in elderly people who undertook an aerobic exercise program differed from that in a control group who did not exercise. The study concluded that exercise has a positive effect on brain plasticity (Colcombe et al., 2004).

However, in targeting patients with cognitive decline resulting from cerebrovascular disorder (CVD), although some reports have documented the effects of interventions such as performing cognitive tasks while exercising (dual task)(Lundin-Olsson et al., 1998), the actual impact of physical activity and exercise alone on cognitive function has not yet been clarified. In a survey of elderly patients with Alzheimer’s disease, those who exercised habitually suffered less from the onset of cognitive decline than those who did not (Larson et al., 2006). If physical activity and exercise were found to affect the cognitive function of patients with CVD, it would be possible to design effective interventions for daily life and rehabilitation. On the other hand, although quantitative data are available for the amount of physical activity undertaken by subjects living at home after the onset of stroke (Field et al., 2013), and some studies have investigated physical activity in CVD patients (Gebruers et al., 2010) and compared the physical activity of hospitalized patients with that of patients at home after discharge (Hosoi et al., 2011), little is known about physical activity in CVD patients during the period of recovery. In the present study, therefore, we evaluated the physical activity of convalescent CVD patients, and assessed its relationship with cognitive function.

There are various approaches for assessment of physical activity level, including subjective evaluations using questionnaires and activity records, and objective evaluations using physical activity meters. In the former case, it has been pointed out that subjective recollection of activity time and action can be inaccurate, that subjective assessment of activity intensity can vary individually, and that evaluation of error can be problematic. In the latter case, on the other hand, it can be difficult to see the kinds of physical activity with wearing the physical activity meters. (Tanaka and Ando, 2014). In the present study, we identified total energy expenditure, including both sitting and inactivity as well as physical activity, using a factorial method combined with a survey of recorded daily living activity. This approach made it easy to predetermine living activities such as meals, sleeping, bathing, grooming activity,
and rehabilitation, as our subjects were hospitalized CVD patients in a convalescent rehabilitation ward. In addition, since the subjects received care through a complete nursing system, with restrictions on discharge without permission, most aspects of the subjects’ daily lives were accurately observed and recorded, making it easier to conduct daily activity surveys. Using the factorial method, we calculated the daily total energy expenditure from the surveyed daily living activity of the patients, and investigated the relationship between total energy expenditure and cognitive function. For evaluation of cognitive function, we adopted the Functional Independence Measure (FIM), hypothesizing that there would be a relationship between total energy expenditure and cognitive function in convalescent CVD patients.

2. Methods

2.1. Participants

The subjects of this study were 24 patients with CVD who were hospitalized at N Hospital. All had completed their acute-stage treatment, were in stable condition, and were ready to begin rehabilitation, which was implemented systematically from the start of hospitalization in the recovery ward. Exclusion criteria were the appearance of delirium and fever symptoms during hospitalization, large fluctuations in mental state, refusal to accept rehabilitation, and inability to stay in the hospital living a regulated life.

2.2. Procedure

From fiscal years 2013 to 2016, 24 subjects who had been hospitalized for five consecutive months in the recovery ward were retrospectively extracted from the medical records. The daily living activities in the records were segmented, extracted, and recorded for each hour, to produce an individual’s table of living activity report. From the table, the total energy expenditure per day was calculated using the factorial method. On the other hand, to evaluate cognitive function, we used FIM scores from tests administered by nurses, physiotherapists, occupational therapists, and speech pathologists. Since the FIM evaluation is conducted regularly every month during hospitalization, we conducted the living activity survey on the same day as the evaluation. First, the value of total energy expenditure per day and cognitive FIM score from the same day were measured monthly for five months after admission, and the changes were noted. Next, we examined the correlation between the total energy expenditure value and the cognitive FIM score for all cases for those five months; we also examined the partial correlation between them using body weight as a control variable. Furthermore, to determine the relationship between the increase in total energy expenditure and the cognitive FIM score using the initial values of the two parameters as control variables. The purpose of the research was fully explained to all subjects, and written informed consent was obtained from all of them. This study was conducted with the approval of the N Hospital Ethics Committee.

2.2.1. Measurement of total energy expenditure

Total energy expenditure of the subjects was measured using a factorial method that estimated and summed the energy expenditure for each physical activity in the survey of daily activities. A lifestyle activity survey table was made to revise each MET (Metabolic Equivalent of Task: MET) value corresponding to activity changes with reference to the “METs table of physical activities” (National Institute of Health and Nutrition, 2012). Conversion to energy expenditure was carried out as follows, with reference to the “Japanese meal intake standard (2015 edition)” (Ministry of Health, Labor and Welfare, 2014).

A) Basic metabolic rate per minute = basic metabolic standard value (kcal/kg/day) × weight (kg) ÷ 1440 (minutes)
B) Metabolic rate at rest per minute = basal metabolic rate per minute × 1.1 (resting metabolism is 1.1 times basal metabolism)
C) Types of activities of daily living, including taking meals, preparation, rehabilitation, voluntary training, sitting, resting, and sleeping. Energy necessary for each activity of daily life = metabolic rate at rest (kcal/min) × time required (minutes) × METs
D) Total energy expenditure for each time obtained in (C) was totaled.
E) The diet-induced heat production from the sum of (D) was considered; division by 0.9 was taken as the total energy expenditure for the day.

2.2.2. Measurement of cognitive function

Cognitive function includes high-level mental activity such as language, action, object recognition, memory, thinking, etc., conducted in the cerebrum (Seki, 2009). In the present study, cognitive function items of the FIM were used to measure the daily cognitive function of the subjects. FIM is an index for evaluation of Activities of Daily Living (ADL) widely used all over the world. It includes four exercise items: self-care (Eating・Grooming・Bathing・Dressing [upper body])・Dressing [lower body]・Toileting); Bladder Management・Bowel Management; Transfers (Bed・Chair)・Transfers (Toilet)・Transfers (Tub・Shower) Walk・Wheelchair ・Stairs. It also includes two items on cognitive function (Cognitive Comprehension・Expression); and Social Interaction・Problem Solving・Memory, for a total of 18 items. In addition, ratings were out of a possible 126 points, with grading per criterion ranging from completely self-sufficient (7 points) to requiring full assistance (1 point). Items related to cognitive function totaled 35 points. Conventionally, cognitive function measurement uses a neuropsychological examination that evaluates various aspects such as attention, memory, intellectual function, executive functions, etc., in a quiet environment for each function. However, in this study, we adopted cognitive function item scores for FIM comprehensively evaluated from the living situation during hospitalization.

2.2.3. Statistical analysis

The data for each variable are given as an average value with standard deviation. First, average values per month for total energy expenditure and cognitive FIM scores were calculated, and repeated measures ANOVA was performed on the difference from the time of admission to the 5th month. Next, the relationship between the total energy expenditure value and cognitive FIM score for all 5 months was analyzed using Pearson’s correlation coefficient. In addition, considering that total energy expenditure is affected by body weight, partial correlation analysis was performed using the subjects’ body weight as a control variable. Subjects were classified into two groups: (1) mild stroke, and (2) moderate-severe stroke, using the National Institutes of Health Stroke Scale (NIHSS) (Brott et al., 1989). Among the 24 subjects, 4 were classified into the mild group, with NIHSS scores of 1-4 points. For these subjects, the average initial value of total energy expenditure was 1697 kcal, and the average initial value of cognitive FIM was 24 points, which was quite high. Therefore, the increase in these variables over the five-month period was relatively small, and these small values were regarded as outliers with regard to all subjects. These 4 cases were therefore excluded from the investigation of the association between the increase of total energy expenditure and the increase of cognitive FIM. We analyzed these increases in the cognitive FIM of the 20 remaining subjects in the moderate to severe group. To investigate the relationship between the increase of total energy expenditure and the increase in cognitive FIM, partial correlation analysis was performed using the initial value for total energy expenditure and the initial cognitive FIM as control variables. For statistical analysis, we used the IBM SPSS statistics package version 24, and the significance level was set at 5%.

3. Results

3.1. Characteristics of subjects

The characteristics of the subjects are listed in Table 1. Mean energy expenditure at the time of admission was 1817±389 kcal, and the mean value of cognitive FIM at that time was 17.3±8.2 points (full score 35 points).

3.2. Total energy expenditure and cognitive function transition over five months

Figures 1A and B show changes in the mean value of total energy expenditure and cognitive FIM, respectively, for all 24 subjects over the five-month period. Repeated measures ANOVA of the difference between the mean values for total energy expenditure, and between the mean values for cognitive FIM, were significant (F (4, 92) = 17.771, p < 0.001; and F (4,92) = 27.371, p < 0.001, respectively). Multiple comparison using the Tukey method showed a significant difference between the
Table 1 Characteristics of the study participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>68.8 ± 10.6 (43–86)</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>16/8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.8 ± 8.7 (145.0–179.0)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>55.6 ± 8.9 (37.0–69.0)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.2 ± 3.1 (17.5–30.7)</td>
</tr>
<tr>
<td>TEE 1st month (kcal/day)</td>
<td>1817 ± 389 (1133–2762)</td>
</tr>
<tr>
<td>TEE 5th month (kcal/day)</td>
<td>1952 ± 391 (1240–2975)</td>
</tr>
<tr>
<td>Cognitive FIM 1st month (point)</td>
<td>17.3 ± 8.2 (6–34)</td>
</tr>
<tr>
<td>Cognitive FIM 5th month (point)</td>
<td>23.3 ± 7.3 (15–34)</td>
</tr>
<tr>
<td>Disease type (number)</td>
<td></td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>12</td>
</tr>
<tr>
<td>Cerebral hemorrhage</td>
<td>9</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>2</td>
</tr>
<tr>
<td>Encephalitis/Encephalopathy</td>
<td>1</td>
</tr>
<tr>
<td>Paralyzed side (number)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>8</td>
</tr>
<tr>
<td>Left</td>
<td>12</td>
</tr>
<tr>
<td>Both</td>
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</tr>
<tr>
<td>None</td>
<td>3</td>
</tr>
<tr>
<td>NIHSS (number)</td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
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</tr>
<tr>
<td>Moderate</td>
<td>17</td>
</tr>
<tr>
<td>Mild</td>
<td>4</td>
</tr>
<tr>
<td>Period from onset to hospitalization (day)</td>
<td>40.9 ± 17.7 (19–85)</td>
</tr>
</tbody>
</table>

Mean ± SD (range)
BMI: Body Mass Index
FIM: Functional Independence Measure
NIHSS: National Institute of Health Stroke Scale

1st, 2nd, 3rd, 4th, and 5th months in total energy expenditure, as well as between the 1st, 2nd, 3rd, 4th, and 5th months, and the 2nd and 5th months in cognitive FIM.

3.3. Relationship between total energy expenditure and cognitive FIM

Figure 2 shows the relationship between total energy expenditure and cognitive FIM for the five-month period in all 24 subjects. There was a significant correlation, \( r = 0.294 \) (\( p = 0.001 \)). In addition, partial correlation analysis using body weight as a control variable revealed a significant partial correlation between the value of total energy expenditure and that of cognitive FIM, \( r = 0.213 \) (\( p = 0.020 \)). It was found that the higher the value of total energy expenditure, the higher the value of cognitive FIM.

3.4. Relationship between increase of total energy expenditure and increase of cognitive FIM in subjects with moderate and severe CVD

We studied the 20 subjects in the moderate to severe CVD group. Tables 2 A and B present the increase in total energy expenditure and the increase of cognitive FIM, respectively, in the 20 subjects as the results of the partial correlation analysis using each initial value as the control variable. In the analysis using initial total energy expenditure as the control variable, \( r = 0.448 \) (\( p = 0.054 \)) was obtained for three months, and \( r = 0.347 \) (\( p = 0.146 \)) for five months. On the other hand, when the cognitive FIM initial value was used as a control variable, \( r = 0.466 \) (\( p = 0.044 \)) was obtained at 3 months, and \( r = 0.485 \) (\( p = 0.035 \)) at 5 months. Thus, a significant partial correlation coefficient was obtained, with higher increases of total energy expenditure corresponding to higher increases in cognitive FIM.

4. Discussion

In order to investigate whether the cognitive function of convalescent patients with CVD is affected by their amount of physical activity, we examined...
the relationship between total energy expenditure and cognitive function for 24 CVD patients hospitalized continuously for about five months in recovery hospital wards. We first evaluated the change in the mean value of total energy expenditure per month, obtained using the factorial method, and in the scores for cognitive function items of the FIM for five months from the time of admission. We then examined the correlation, and the partial correlation using body weight as a control variable between total energy expenditure and the scores for cognitive function items of the FIM for all subjects over the five-month period. Furthermore, we investigated the partial correlation using each initial value of total energy expenditure and cognitive FIM as control variables for 20 subjects in the moderate and severe CVD group.

As shown in Figure 1, the mean value of both the
total energy expenditure and cognitive FIM increased significantly throughout the five-month period. This was considered to indicate the outcome of the intervention to improve physical and cognitive functions within a certain period of time during the period of recovery.

Next, as shown in Figure 2, our analysis revealed a positive correlation between total energy expenditure and cognitive FIM within the five months of hospitalization ($r = 0.294$, $p = 0.001$). Furthermore, it was shown that there was a significant partial correlation when body weight was used as a control variable ($r = 0.221$, $p = 0.016$). Therefore, we determined that the higher the total energy expenditure, the higher the cognitive FIM value became.

We then considered the relationship between increase of total energy expenditure and increase of cognitive FIM in the 20 subjects with moderate and severe CVD. As shown in Table 2, in the partial correlation analysis using the initial value of cognitive FIM as the control variable, the partial correlation coefficient was $r = 0.466$ ($p = 0.044$) at three months and $r = 0.485$ ($p = 0.035$) at five months, which indicated significance. It was found that the higher the total increase in energy expenditure, the higher the cognitive FIM increase became. These results indicated that the increase of total energy expenditure and the increase of cognitive FIM in the moderate to severe stroke group were related during the convalescence stage. On the other hand, a significant correlation was also observed when the initial value of the cognitive FIM was used as the control variable. There were differences between individuals in the initial value of total energy expenditure and cognitive FIM, as shown in Table 1, the initial value of total energy expenditure ranging from 1133 to 2762 kcal, and the initial value of cognitive FIM ranging widely from 6 to 34. This was because cognitive function in the moderate to severe stroke group would have been affected by the complicated reconstruction of the nervous system that occurred in the recovery phase, and in some cases consciousness disorder and language dysfunction remained (Marsh et al., 2006). Moreover, it is considered that there were differences between individuals in the initial value of cognitive FIM. Therefore, it seems that a more significant correlation was obtained over a wider range in partial correlation analysis using the initial value of the cognitive FIM than for that using the initial value of the total energy expenditure as the control variable.

Similarly to previous studies, the present one found that physical activity and exercise in non-demented elderly individuals had a positive effect on cognitive function. We attempted to clarify whether the cognitive function of CVD patients was affected by physical activity using a method that focused on total energy expenditure, which was calculated by a factorial method based on a survey of subjects’ living activities. On the other hand, we investigated
the relationship between activity and cognitive function by referring to FIM measure scores, and found that there was a significant correlation between them. However, it was assumed that calculation of energy expenditure using a factorial method would have introduced error by deviating from exact times and not capturing single behaviors. Also, since total energy expenditure also includes energy expenditure at rest, it could not be regarded as an indicator of the amount of physical activity in the strict sense. Therefore, it will be necessary to measure and confirm the amount of physical activity more accurately in the future. On the other hand, regarding FIM, there is a possibility that errors may have arisen due to the judgment of evaluators involved daily with the subjects. In future, we plan to evaluate the various aspects of cognitive function using paper and pencil tests. Furthermore, it will be necessary to examine the total energy expenditure and cognitive function of age-matched healthy subjects as a comparative control group.

In addition, we examined cognitive function in relation to physical activity of subjects with brain damage due to CVD. Podewils et al. (2005) reported that cognition in patients with Alzheimer’s disease was also highly related to energy expenditure and exercise, and that physical activity helped to prevent disease progression. Like that study, the present one found a significant correlation between physical activity and cognitive function of patients with various stages of cognitive decline due to CVD. However, this study did not clarify whether the amount of physical activity influenced cognitive function, or the causal relationship between them. Therefore, in the future, it will be necessary to further investigate, through intervention experiments, whether physical activity is effective for improving the cognitive function of patients with other types of CVD. The aim of rehabilitation is to allow effective teamwork between doctors, nurses, caregivers, therapists, and family members to enhance the recovery of patients. In the future, we hope to verify the impact of physical activity on cognitive function at rehabilitation for brain-damaged people. In addition, we will continue efforts to further the recovery of subjects.

5. Conclusions

We examined the relationship between physical activity and cognitive function in convalescent patients with CVD. Total energy expenditure obtained by a factorial method and scores for cognitive function items by FIM increased significantly in the five months after hospital admission. Furthermore, total energy expenditure and the cognitive FIM values in all subjects were significantly correlated at five months; moreover, there was a significant partial correlation when body weight was used as a control variable. Our findings showed that the higher the total energy expenditure, the higher the value of cognitive FIM. Furthermore, there was a significant partial correlation between the increase of total energy expenditure and the increase of cognitive FIM in the moderate to severe CVD group when the initial value of cognitive FIM was used as a control variable; the higher the increase of total energy expenditure, the higher the observed increase of cognitive FIM.

References


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Ministry of Health, Labor and Welfare Statistics and Infor-


