The Relationship Between Energy Expenditure and Physical Functions in Patients Hospitalised For Stroke

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Abstract

We assessed the relationship between energy expenditure (EE) and functional independence measure (FIM-M) score, Berg Balance Scale (BBS), and comfortable walking speed (CWS) in patients hospitalised for stroke. The total EE per day (TEE), EE during rehabilitation (REE), and EE during activities other than rehabilitation (OEE) were measured using a single-axis acceleration sensor in 36 patients hospitalised for a first stroke episode. In addition, the relationships between each type of EE and FIM-M, BBS, and CWS were investigated. In these patients (mean age 66.2±10.6 years), the median values of TEE, REE, and OEE were 41.8 kcal, 18.5 kcal, and 16.6 kcal, respectively. Correlations were observed between each EE type and all physical function indices. Following the stratification of patients into two groups (high and low) based on the level of physical function, a significant correlation between EE type and physical function was observed only in the low BBS group. EE was correlated with overall physical function indices, but the trend differed depending on physical ability. When patients were stratified based on ability, there were several groups with no significant correlation. Therefore, many patients were unable to achieve an appropriate EE for their level of physical function.

Introduction

People with low daily physical activity experience deterioration of physical function [1], whereas those with high physical activity have lower mortality rates and lower incidence of ischemic heart disease and hypertension [2–4]. In addition, physical activity centred around walking is known to reduce mortality rates in older adults [5], emphasizing the importance of physical activity in an antigravity position. Physical activity is any movement of the body's skeletal muscles that causes energy expenditure (EE), including exercise, housework, and work [6]. The Physical Activity Standard for Health Promotion 2013 [7] established by the Ministry of Health, Labor, and Welfare recommends that persons older than 65 should perform 40 min of physical activity every day. This includes exercises of three metabolic equivalents (METs) or more to maintain and improve physical function.

A study in which the EE of older adults was calculated using a questionnaire [8] reported that physical activity of 1000 kcal (142 kcal/day) or more for at least 1 week improved lower limb muscle strength, walking speed, and balance ability. Conversely, the modified Rankin Scale scores of stroke patients bedridden for long durations during hospitalisation were higher after 3 months, and their degree of functional independence decreased [9]. Moreover, a relationship between increased sitting time and decreased physical function has been reported [10]. Hence, for stroke patients to maintain and improve function, they must engage in daily physical activity.

The best method to measure EE has not been established. A previous study used an accelerometer to measure EE in 40 stroke patients in a community setting and found that more than half had low physical activity, below the 142 kcal/day recommended for the elderly [11]. Furthermore, it has been reported that hospitalised stroke patients have significantly lower EE than healthy controls and spend less time being active, even when they have a high capability for physical activity [12,13]. In addition, the total duration of physical therapy (PT) and occupational therapy (OT) in stroke patients per day has been estimated to be 70 minutes [14]. Thus, although stroke often causes physical ability to deteriorate, these patients do not engage in an appropriate amount of physical activity.

The type of exercise also plays a role in increasing physical function. A previous study of stroke patients within 6 months after onset [15] found that physical activity time in an antigravity position, such as standing or walking, was positively correlated with the Berg Balance Scale (BBS) and Barthel Index (BI). In addition, compared to conventional therapy, increased physical activity time in an antigravity position during rehabilitation led to an improvement in the functional ambulatory category of the Rivermead Motor Assessment Scale, which assesses gait [16]. Further, walking speed, FIM-M, BI, and other indices have been reported to improve with increased rehabilitation time and activity in an antigravity position [17,18].

What is the best way to quantify physical activity? A previous review assessing the amount of physical activity in stroke patients [19] analysed 60 studies that used equipment (accelerometer and pedometer) to measure physical activity and 31 studies that used an observation method. Physical activity in these studies comprised activity time, activity intensity, and the number of activities over a 3-day period, all of which are simple and reliable to measure in a clinical setting [19]. However, an accelerometer is an objective and valid tool to measure activity in stroke patients, and a significant correlation between METs obtained from uniaxial accelerometers and calorimetry in patients with brain injury has been shown [11,20]. Physical activity is often measured using activity time and not EE. However, physical activity refers to all activities that lead to EE [6]. Importantly, activity time does not reflect the intensity of the activity. For example, EE changes when walking speed is adjusted even if the walking time remains the same. Therefore, EE better reflects physical activity than activity time.

Stroke patients should increase their physical activity overall. Of the total EE (TEE) per day in hospitalised stroke patients, EE during rehabilitation (REE) is critical, but it is also important to increase EE at times other than during rehabilitation (OEE); however, no studies have specifically examined REE and OEE. Therefore, this study sought to measure the TEE, REE, and OEE in subacute stroke patients and to assess their relationship with physical function indices (FIM-M, BBS, and CWS). We hypothesised that there is a correlation between REE, but not OEE, and physical function. Therefore, this study aimed to identify an appropriate EE that contributes to improving physical function in subacute stroke patients.

Results

Patient characteristics

Forty-six patients were selected; however, 4 patients did not give consent and were excluded. Of the remaining 42 patients, 6 were considered to have decreased motivation and were excluded. Of the 36 included patients, 25 were males and 11 were females; their average age was 66.2±10.6 years (Table 1).

Relationship between physical function and EE

The median FIM-M, BBS, CWS, TEE, REE, and OEE were 75 points, 47 points, 0.62 m/s, 41.8 kcal, 18.5 kcal, and 16.6 kcal, respectively (Table 2). The correlations between FIM-M, BBS, CWS, TEE, REE, and OEE are shown in Table 3. There was a significant correlation between all physical functions and each EE type.

Figure 1 shows the scatter plot of physical function and TEE. Although there was a statistically significant correlation between physical function indices and EE, patients with high function had a wide range of EE compared to patients with low function. It was visually confirmed that some of the patients were active, and some were barely active. This trend was observed between all EE and physical function indices.

Relationship between physical function and EE stratified by physical function

The FIM-M high score group (TEE: ρ=0.274, not significant [ns]; REE: ρ=0.209, ns, OEE: ρ=0.265, ns) and low score group (TEE: ρ=-0.030, ns; REE: ρ=-0.014, ns; OEE: ρ=-0.045, ns) showed no significant correlation with any EE type (Table 4).

In the BBS high score group, no significant correlation was observed (TEE: ρ=0.291, ns; REE: ρ=0.302, ns; OEE: ρ=0.288, ns). However, in the BBS low score group, there was a significant correlation with all EE types (TEE: ρ=0.691, $p<0.01$; REE: ρ= 0.675, $p<0.01$; OEE: ρ=0.551, $p<0.01$) (Table 4).

The CWS high score group showed a significant correlation with all EE types (TEE: ρ=-0.469, $p<0.01$; REE: ρ=-0.440, $p<0.05$; OEE: ρ=-0.436, $p<0.05$). However, no significant correlation was observed with any EE type in the low score group (TEE: ρ=-0.500, ns; REE: ρ=-0.700, ns; OEE: ρ=-0.300, ns) (Table 4).

Figure 2 shows a scatter plot of both the FIM-M high and low score groups as well as the BBS high and low score groups. The CWS low score group had only five patients; therefore, the scatter plots for high and low score groups are not shown. There was no significant difference in the scatter plot combining the high and low CWS score groups.

Discussion

Askim et al. [15] previously reported that physical activity time in an antigravity position was positively correlated with improved physical function, including BBS and BI scores. Similar to rehabilitation, physical activities other than those performed during therapy affect physical ability. The present study found a correlation between all EE types and physical function, supporting previous studies. Although we observed a correlation between EE and overall physical function, the trend differed based on ability level. A significant correlation was observed only in the BBS low group and in the CWS high group. However, no significant correlation was found between the other physical function subgroups and EE types.

The REE of many patients was similar to the OEE, irrespective of the time spent in rehabilitation. In addition, there were several patients with an REE lower than the OEE. Therefore, it is highly possible that the therapy comprised mostly interventions in the lying or sitting position and few activities in the antigravity position. Conversely, the fact that some patients expended small REE despite the physical capacity to increase it suggests that antigravity activity was not sufficiently administered. Therefore, physical function can be improved by increasing antigravity activity.

There was no significant correlation with any form of EE in the FIM-M group, even after it was stratified into high and low scoring groups, suggesting that not enough energy commensurate with activities assessed with the FIM-M was expended throughout the day, even during rehabilitation. The high score FIM-M group consisted of patients who walk with self-support, a group with high physical function. Interestingly, there was a patient who walked independently whose REE was equivalent to the OEE of the FIM-M low score group, suggesting that the rehabilitation exercises were mostly in the lying or sitting position with few in an antigravity position. In addition, the OEE of most patients in the FIM-M high score group was equivalent to that of the FIM-M low score group, suggesting that there was little antigravity activity during times other than rehabilitation. Therefore, it is recommended to provide lifestyle guidance on activities such as standing and walking to these patients.

In the low BBS group, which had a high risk of falling such that many patients needed monitoring during walking, there was a significant correlation with every EE index, suggesting that enough energy was being expended for balance. However, many patients in the low BBS group had an REE equivalent to the OEE of patients in the low FIM-M group. It is therefore highly likely that antigravity activity was insufficient during rehabilitation. In addition, most patients in the low BBS group had an OEE equivalent to that of the low FIM-M group, who also required monitoring during walking.. Conversely, in the high BBS group, no correlation was found with any type of EE; thus, not enough energy was expended for balance. Although the high BBS group had good balance and a low risk of falling, there were patients in this group whose REE was equivalent to the OEE of patients in the low FIM-M group; hence, these patients may not be able to fully perform activities, such as walking during rehabilitation. The OEE of patients in the high BBS group was similar to that of patients in the low FIM-M group, even though their balance was good, suggesting that they did not spend much non-rehabilitation time performing activities in an antigravity position.

In the high CWS group, there was a significant correlation with every type of EE. Each EE index was expended throughout the day, during rehabilitation, and at times other than rehabilitation, commensurate with physical function. The number of patients in the low CWS group was small, and there was no correlation with any EE index.

Although all patients were able to walk without special assistance, they were accompanied in case of an emergency. Therefore, it is possible to increase antigravity activity during times other than rehabilitation by improving the environment of the ward, providing walking aids, and securing caregivers other than nurses, such as family members. By doing so, a more appropriate OEE can be achieved, thereby improving physical function. Furthermore, a previous study reported that even if the physical activity of stroke patients throughout the day was the same, EE could be increased by incorporating more intense activity [8]. Additionally, the authors reported that EE was higher when performing many physical activities at a lower intensity than while being inactive [8]. Therefore, increasing the intensity and frequency of physical activity improves prognosis in stroke patients. The amount of physical activity recommended for the elderly is 1000 kcal or more per week (142 kcal or more per day). The median TEE of our study, which is the EE per day, was 41.8 kcal.

One limitation of this study is that the single-axis accelerometer underestimates the actual EE by 8% [21], and the patient's unique gait may affect the readings. Another limitation is the small sample size, and the results are only from one facility; thus, other facilities should be included in future research. Finally, since this study is a cross-sectional study, it was impossible to examine the causal relationship; therefore, future studies could adopt a longitudinal design to evaluate the effect of EE in an antigravity position on function in subacute stroke patients.

In conclusion, we found that EE was correlated with overall physical function indices, but the trend differed depending on the level of physical function. When patients were stratified based on this level, several groups showed no significant correlation. Therefore, many patients were unable to achieve EE in an antigravity position commensurate with their physical ability. However, even when a correlation is found between each physical function index and EE type, it does not necessarily mean that an appropriate amount of EE was achieved, as the EE of the patients in this study was likely to be less than recommended. Nevertheless, the median values of TEE (41.8 kcal), REE (18.5 kcal), and OEE (16.6 kcal) obtained from the accelerometer in this study can be used as references in future research.

Methods

Target population

A cross-sectional study was conducted on first-stroke patients who were hospitalised in a convalescent rehabilitation ward. The patients could walk for more than 16 m without physical assistance, regardless of whether they had walking aids or orthosis. Exclusion criteria included neurological disorders other than stroke that significantly limited movement, cardiovascular disorders, orthopaedic disorders, cognitive dysfunction and higher brain dysfunction, markedly decreased motivation (apathy scale 16 points or more) [22], and sleep disorders (see Supplementary Fig. 1 for a flowchart of the study design).

Activity measurement

Vertical acceleration was measured using a single-axis accelerometer (Lifecorder, Suzuken Co. Ltd, Nagoya, Japan), measuring 62 × 46 × 26 mm and weighing 40 g. The sampling frequency was 32 Hz, and the range of acceleration was 0.06–1.94 *g* (1.00 *g* is the acceleration of free fall: 9.807 m/s^2). Activity was classified into 11 levels every 4 s (0.0, 0.5, and 1.0–9.0; 0.0 is less than 0.06 *g*). Activity level was converted to EE (kcal) using the following procedure. When the accelerometer detected three or more acceleration signals within 4 s, the activity was recognized as physical activity and classified as one of nine activity levels (1.0–9.0). Subsequently, EE was calculated as follows (Eq. 1) using Ka calculated from the weight (W) and the activity level [21].

$EE (kcal) = Ka \times W (kg)$ (1).

Ka is not disclosed because it is proprietary.

EE detected by the accelerometer was compared with measurements made with a respiratory chamber, and there was a significant correlation between walking EE ($\rho = 0.928$, $p < 0.001$) and non-walking EE ($\rho = 0.477$, $p < 0.001$), in agreement with an earlier study [21].

Research procedure

After obtaining consent from each patient who met the inclusion criteria, apathy scales were measured, and those with a score of ≥ 16 were excluded [22]. We obtained data on age, sex, height, weight, diagnosis, and paralyzed side. We entered the age, sex, height, and weight of each patient in the accelerometer. We ensured the patient wore the accelerometer on the designated part of the body.

For three days (starting from 9:00 am each day), the patient wore the accelerometer on the trousers of the non-paralyzed limb or belt (upper anterior iliac spine), and EE (kcal) was recorded throughout the day except during bathing and sleeping. The purpose of the study was explained to the physical and occupational therapists in charge, and routine intervention was performed to improve the physical and mental function of the patient.

PT and OT were conducted every day for 20–80 minutes per session. The presence of the accelerometer was confirmed, and the start and end times of each session were recorded by the therapist. The amount of physical activity was calculated by summing the EE measured every minute by the accelerometer for each day and computing the average over 3 days.

After measuring activity for 3 days, each therapist evaluated physical function using FIM Motor items (FIM-M), BBS, and 10 m CWS. FIM, an evaluation scale for activities of daily living, rates functional independence. FIM-M has a total of 91 points corresponding to 13 items, including eight items on self-care, three items on transfer, and two items on movement. BBS is a comprehensive evaluation of balance ability consisting of 14 items, including posture maintenance in sitting and standing positions, standing motion, one-leg standing, transfer motion, and direction change. Each item is scored on a scale of 0–4, for a possible total of 56 points. The 10 m CWS was measured by setting a 10 m walkway and a 3 m front and back runway. The apathy scale comprises 14 items, and motivation is evaluated by a questionnaire in which each question is worth 0–3 points. A high score indicates low motivation, and a low score indicates high motivation. A patient with a score of ≥ 16 was considered as “demoralized” [22].

Statistical analysis

SPSS Statistics Ver23 (IBM Corp, Tokyo, Japan) was used for statistical analysis. The Shapiro–Wilk test was used to assess normality. Since the data were non-normally distributed, Spearman’s rank correlation coefficient was used to test the relationship between groups. The significance level was set at $\alpha < 5\%$.

Since the scatter plots indicated that the EE range of patients with high function was wider than that of patients with low function, we stratified the patients into two groups for each index. For FIM-M, the group that was independent enough to not need monitoring in FIM gait items (6,7 points) was considered the high score group, and the group that required monitoring (5 points) was considered the low score group. Based on the criteria to determine the risk of falls [23,24], patients with BBS score ≥ 46 points were classified as the high score group, and patients with ≤ 45 points were classified as the low score group. For walking speed, based on the criteria for indoor walking independence [25], we considered the group faster than 0.27 m/s as the high score group and slower than 0.27 m/s as the low score group.

Declarations

Ethics approval and consent to participate.

Study approval was obtained from the Shinshu University Medical Ethics Committee (approval number: 3555). All participants provided informed consent. All research was performed in accordance with relevant guidelines or regulations.

Conflicts of interest

There are no conflicts of interest to disclose.

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Tables

Table 1. Patient characteristics (n=36)

Variable	Value
Age (years)	
Mean±SD	66.2±10.6
Median (range)	64 (46-86)
Sex, n	
Male	25
Female	11
Period from onset (days)	
Mean±SD	55.2±39.9
Median (range)	47.5 (15-211)
Cerebral haemorrhage, n (%)	13 (36)
Cerebral infarction, n (%)	23 (64)
Paralyzed side, n	
Right	18
Left	18
Modified Rankin Scale, n	
1	1
2	10
3	4
4	21
Body mass index, kg/m^2	
Mean±SD	23.8±4.5
Median (range)	22.8 (18.0-38.7)

Table 2. Median and range of each physical function and energy expenditure (n=36)

	Median	Range
FIM-M [a] (point)	75	46-91
BBS [b] (point)	47	24-56
CWS [c] (m/s)	0.62	0.11-1.32
TEE [d] (kcal)	41.8	2.9-152.3
REE [e] (kcal	18.5	0.1-114.1
OEE [f] (kcal)	16.6	2.8-75.7

[a] Functional Independence Measure Motor score, [b] Berg Balance Scale,

[c] 10 m comfortable walking speed, [d] Total energy expenditure per day, [e] Energy expenditure during rehabilitation, [f] Energy expenditure other than during rehabilitation

Table 3. Correlation coefficient between physical function and energy expenditure

	TEE [d]	REE [e]	OEE [f]
FIM-M [a]	0.424**	0.361*	0.436**
BBS [b]	0.592**	0.657**	0.465**
CWS[c]	0.544**	0.507**	0.499**

** p<0.01, * p<0.05

[a] Functional Independence Measure Motor score

[b] Berg Balance Scale

[c] 10 m comfortable walking speed

[d] Total energy expenditure per day

[e] Energy expenditure during rehabilitation

[f] Energy expenditure other than during rehabilitation

Table 4. Correlation coefficient between high and low levels of physical function and each energy expenditure (Spearman's rank correlation coefficient)

	FIM-M [d]		BBS [e]		CWS [f]	
High Low (n)	High (15)	Low (21)	High (21)	Low (15)	High (31)	Low (5)
TEE [a]	0.274	-0.030	0.291	0.691**	0.469**	0.500
REE [b]	0.209	-0.014	0.302	0.675**	0.440*	0.700
OEE [c]	0.265	-0.045	0.288	0.551**	0.436*	0.300

** p<0.01, * p<0.05

[a] Total energy expenditure per day

[b] Energy expenditure during rehabilitation

[c] Energy expenditure except during rehabilitation

[d] Functional Independence Measure Motor score

[e] Berg Balance Scale

[f] 10 m comfortable walking speed

Figures

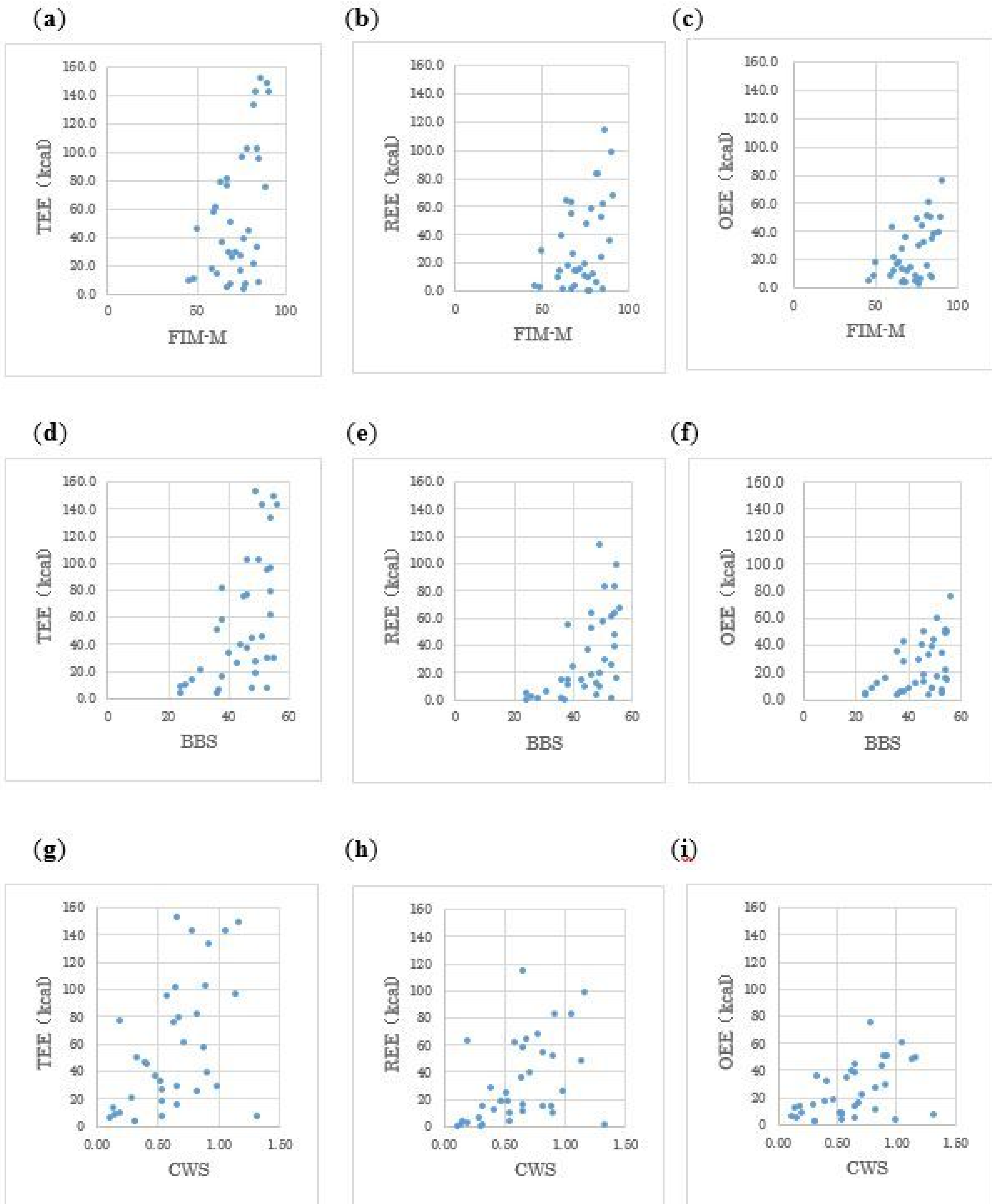

Figure 1

Scatter plots of physical function and energy expenditure (n=36)

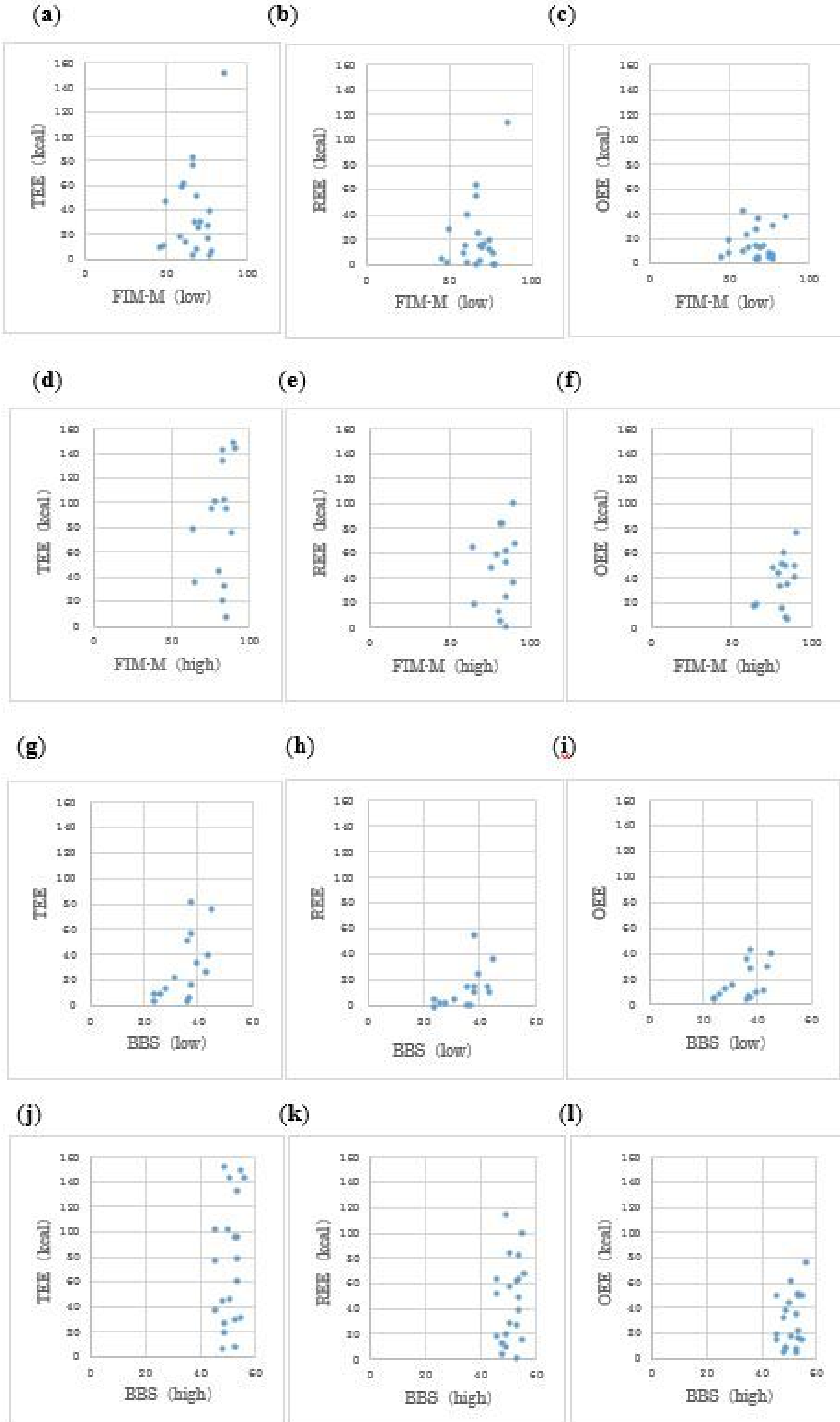

Figure 2

Scatter plots of physical function (high and low score groups of FIM-M and BBS) and energy expenditure

Supplementary Files

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