The known-groups validity of intensity-based physical activity measurement using an accelerometer in people with subacute stroke

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Abstract. [Purpose] This study aimed to assess the known-groups validity of the estimated metabolic equivalents during physical activities using accelerometer, Active Style Pro HJA 350-IT, in people with subacute stroke. [Subjects and Methods] Ten participants with subacute stroke and ten healthy people performed six activities (lying, sitting, standing, sitting with reaching task, standing with reaching task, and walking) and metabolic equivalents were estimated using the accelerometer during each activity. These estimated metabolic equivalents were compared with reported metabolic equivalents through compendiums or previous studies. Additionally, the estimated metabolic equivalents were compared between subacute stroke and healthy control participants. [Results] The estimated metabolic equivalents of both groups during maintaining posture showed significantly lower values in comparison with previous studies. There were no significant differences between the estimated metabolic equivalents during sitting with reaching tasks or standing with reaching tasks when compared with compendium metabolic equivalents across both groups. The estimated metabolic equivalents during walking were inevitable values significantly differed from previous study which conducted with stroke patients with lower gait abilities in both groups. [Conclusion] The estimated metabolic equivalents using accelerometer may be suitable to assess movement activity rather than motionless activity, and accelerometer demonstrated acceptable validity in people with subacute stroke.

Key words: Subacute stroke, Physical activity, Known-groups validity

INTRODUCTION

Over the past few years, many researchers and clinicians have shown an interest in increasing physical activity in people with stroke. Several previous studies have reported that increasing physical activity was beneficial to decrease the risk of recurrent stroke1, 2) and promoting the improvement of post stroke disabilities3, 4). Despite these studies, people have developed an inactive lifestyle at several stages of post-stroke5, 6). Thus, increasing physical activity is an important treatment target for people with subacute stroke.

When increasing physical activity in subacute stroke patients, there is a need to validate the monitoring method of physical activity. An accelerometer has been known to be a useful device to provide quantitative evaluation of physical activity7, 8). Current systematic review has reported that 11 devices have been investigated for validity of measurement of physical activity in people with stroke9). Of these, eight devices have shown good criterion validity of physical activity measurement such as step count10–13), number of transitions14), activity count15), walking duration16), time of posture17) or energy expen-
SUBJECTS AND METHODS

This is a known-group validity study on measurement of METs in subacute stroke patients. Ten subacute stroke patients and 10 healthy young adults were recruited in this study. The healthy young adults were recruited from the hospital’s employees and served as the control group. The participants with subacute stroke were recruited from a rehabilitation hospital in Tokyo, Japan. The inclusion criteria were selected based on previous studies as follows: (1) first stroke, (2) at least one month after stroke onset before commencing this study, (3) no medical conditions other than stroke affecting their ability to walk, (4) ability to walk independently with or without a walking device and lower limb orthotic, and (5) sufficient cognitive ability to understand performance tasks in this study protocol and to provide informed consent.

To define the characteristics of the participants, data on age, gender, body mass index (BMI), and medication status regarding beta-blockers were collected from all participants. BMI was calculated using height and weight measured using a wall-mounted height meter ruler and a digital scale, respectively. The time since stroke, type of stroke, hemiparetic side, severity of hemiparesis (assessed with Brunnstrom stage of paretic lower limb), and independence of walking (assessed with functional ambulation category (FAC)) were also collected from the participants with subacute stroke. All participants were given verbal and written information regarding the study contents and purpose, and signed informed consent was obtained. This study was approved by the ethical committee of Kyorin University of Health Sciences (approval number: 28-9).

Six activities were constructed to evaluate the validity of the measurement of estimated METs by accelerometer using two types of activities (maintaining posture and movement activity). The activities for maintaining posture were lying, sitting, and standing. The movement activities were sitting with reaching task, standing with reaching task, and walking. The methods of conducting these activities were determined based on previous studies. Lying was performed in a relaxed supine position. Sitting participants were asked to maintain the sitting position on a chair without a backrest. Standing participants were asked to maintain a standing position in a fundamental standing position without assistance.

For movement activities, the procedures of the sitting with a reaching task and the standing with a reaching task were assessed using the methods of standing with reaching task by Kafri et al. as a reference. Participants sat on a chair without a backrest for the sitting with reaching task. They were instructed to use the non-paretic side of the upper-limbs to move book clips from the table which was placed on one side of the body and move the clip forward to the other side of the table. For the standing with reaching task, participants were asked to stand on a foam cushion and use the non-paretic side of the upper-limbs to move book clips from the table which was placed on one side of the body and move the clip forward to the other side of the table, with similar table position as the sitting with reaching task. The frequency of reaching in both testing activities was set at one reach per three seconds which was calculated from a mean value of performed reaching frequency in a stroke group in a previous report by Kafri et al.

To dictate the timing of reaching, digital auditory metronome was used in this study.
A six-minute walking test was used as walking activity. The instructions for the test asked the participants to walk around 60 meters of oval track as many times as possible in six minutes. The six-minute walking distance (6MD) was calculated from the six-minute walking test.

In all testing activities, participants who used a lower limb orthotic or a cane in daily life, were allowed to use these walking aids. Before beginning a testing session, participants rested in relaxed spine position for three minutes. Participants were then asked to maintain each testing activity. The duration time for each testing activity was: three minutes in lying, five minutes in sitting, standing, sitting with reaching task, standing with reaching task, and six minutes for walking. A rest break of three minutes was provided between each testing activity.

Physical activity was measured using the Active Style Pro HJA350-IT. The accelerometer [size, 74 × 46 × 34 mm; weight, approximately 60 g; and sensitivity, 0.003 –6 G force (1 G=9.807 m/s²)] was designed to be attached to a waist belt. The accelerometer was worn on a waist belt on the non-paretic or dominant-hand side in participants with subacute stroke or healthy control, respectively. The MET data were recorded every 10 seconds and were processed using the manufacturer’s software (HMS-HJA-IC01 J, OMRON, Kyoto, Japan). Mean values of the MET data were calculated from the cumulative time for each testing activity.

To verify known-group validity of the measurement of estimated METs in people with subacute stroke, the compendium of physical activities by ACSM was selected as a main reference value in this study. The compendium of physical activities has widespread acceptance as a resource to estimate and classify the energy cost of human activities and has been used as a reference to monitor lifetime physical activity in affected individuals. Of these, we selected six codes for specific activities which were most similar to activities in this study as a reference for verification of the validity of measurement of estimated METs in this study’s participants. The selected six codes of physical activities were as follows: 7011 for lying; 7021 for sitting; 7040 for standing; 07022 for sitting with reach task; 07041 for standing with reach task; and 17220 for walking. The codes for walking activities were selected based on the mean gait speed during the six-minute walking test of the participants with subacute stroke and healthy control in this study.

The estimated MET values for participants with subacute stroke during maintaining a posture by the accelerometer [lying (0.5 ± 0.5 METs), sitting (0.8 ± 0.4 METs), and standing (1.1 ± 0.2 METs)] showed significantly lower values compared with the generalized MET values by ACSM or an estimated MET value in people with stroke from previous studies. The estimated MET values in the healthy control group were also compared with the generalized MET values in the compendium of physical activities by ACSM or the estimated MET values in people with stroke in previous studies by one sample t-test in each activity. All analyses were performed using SPSS (IBM SPSS version 23.0, IBM Corp, Chicago, IL, USA). The threshold for significance was p<0.05.

RESULTS

The characteristics of all participants are summarized in Table 1. The participants with subacute stroke showed significantly higher age, lower six-minute walking distance, and lower mean gait speed during the six-minute walking test than the healthy control.

The estimated MET values for participants with subacute stroke during maintaining a posture by the accelerometer [lying (0.5 ± 0.5 METs), sitting (0.8 ± 0.4 METs), and standing (1.1 ± 0.2 METs)] showed significantly lower values compared with the generalized MET values by ACSM. The estimated MET values during walking in subacute stroke group (3.8 ± 0.9 METs), showed significantly higher values than the generalized MET values of walking at 4.0 mph reported by ACSM (5.0 METs). There were no significant differences between the MET values during sitting with reaching task or standing with reaching task among subacute stroke (sitting: 1.6 ± 0.3 METs and standing: 1.8 METs). In the healthy control group, the estimated MET values during maintaining posture (lying: 0.4 ± 0.4 METs, sitting: 0.8 ± 0.4 METs and standing: 0.5 ± 0.5 METs) also revealed significantly lower values compared with the generalized MET values by ACSM. There were no significant differences among the estimated MET values during walking in the healthy control (5.5 ± 1.2 METs) and the generalized MET values of walking at 4.0 mph by ACSM (5.0 METs). Additionally, there were no significant differences of the MET values during sitting with reaching task or standing with reaching task among healthy control.
healthy control (sitting with reaching task: 1.6 ± 0.2 METs and standing with reaching task: 1.8 ± 0.1 METs) and ACSM30, 31). The results of comparison of the MET values in participants with subacute stroke versus the healthy control group with the generalized MET values by ACSM30, 31) are summarized at Table 2.

In the participants with subacute stroke, the estimated MET values during lying showed significantly lower values compared with reported MET values by Verschuren et al.25) (1.00 METs). In the sitting and standing activities, there were no significant differences between the estimated METs by the accelerometer in subacute stroke and the reported MET values by Verschuren et al.25) (sitting: 1.07 METs and standing: 1.20 METs). The estimated MET values during the standing with reaching task showed significantly lower values than the reported METs by Kafri et al.26) (1.96 METs). The estimated MET values during the walking activity for participants with subacute stroke, showed significantly higher values than the reported METs by Verschuren et al.25) (2.71 METs).

In the healthy control group, the estimated METs during maintaining posture showed significantly lower values than the reported METs by Verschuren et al.25). There were also significant differences of the MET values during the standing with reaching task and walking between the healthy control group and those from previous studies25, 26). The results of the comparison between the estimated MET values in participants with subacute stroke or healthy control and those MET values reported in previous studies25, 26) are summarized at Table 2.

### Table 1. Participant characteristics

|                      | Stroke (n=10) | Healthy control (n=10) |
|----------------------|--------------|------------------------|
| Age (years)*         | 57.5 ± 16.2  | 27.6 ± 5.6             |
| Gender (men/women, numbers) | 5/5        | 5/5                    |
| Body mass index (kg/m²) | 23.5 ± 3.6  | 21.0 ± 1.9             |
| Six minutes walking distance (m)* | 360.3 ± 124.1 | 663.3 ± 181.5 |
| Mean gait speed during 6 minutes walking test (mph)* | 2.2 ± 0.8 | 4.1 ± 1.1 |
| Beta-blocker medications (numbers) | 2       | 0                      |
| Time since stroke (days) | 86.6 ± 33.6 | -                      |
| Type of stroke (ischemic/hemorrhage, numbers) | 5/5       | -                      |
| Hemiparetic side (right/left, numbers) | 4/6       | -                      |
| Brunnstrom stage of paretic lower limb (I/II/III/IV/V/VI, numbers) | 0/0/0/3/3/4 | -                   |
| Functional ambulation category (1/2/3/4/5, numbers) | 0/0/0/8/2 | -                      |

Values are mean ± standard deviation or number. *Significance differences between groups (p<0.05).

### Table 2. One sample t-test comparing estimated METs in this study with reported METs in ACSM or previous studies

|                      | Stroke | Healthy control | ACSM | Previous studies |
|----------------------|--------|-----------------|------|------------------|
|                      | METs   | METs            | METs | METs             |
| Maintain posture     |        |                 |      |                  |
| Lying                | 0.5 ± 0.5 (0.0–1.2)*† | 0.4 ± 0.4 (0.0–1.1)*† | 1.0a | 1.00f |
| Sitting              | 0.8 ± 0.4 (0.0–1.2)*† | 0.8 ± 0.4 (0.0–1.2)*† | 1.3b | 1.07h |
| Standing             | 1.1 ± 0.2 (0.8–1.5)*† | 0.5 ± 0.5 (0.0–1.1)*† | 1.3c | 1.20i |
| Movement activity    |        |                 |      |                  |
| Sitting with reaching task | 1.6 ± 0.3 (1.3–2.3) | 1.6 ± 0.2 (1.2–2.0) | 1.5d | -          |
| Standing with reaching task | 1.7 ± 0.2 (1.5–2.0)*† | 1.8 ± 0.1 (1.7–2.0)*† | 1.8e | 1.96f |
| Walking              | 3.8 ± 0.9 (2.7–5.4)*† | 5.5 ± 1.2 (4.5–8.5)*† | 5.0f | 2.71k |

Values are mean ± standard deviation (range), and are expressed as metabolic equivalent (MET).

*Significant differences compared with ACSM (p<0.05). †Significant differences compared with previous studies (p<0.05).

*The generalized MET value of lying quietly by ACSM30, 31) (Code number: 07011). †The generalized MET value of sitting quietly by ACSM30, 31) (Code number: 07021). ‡The generalized MET value of standing quietly by ACSM30, 31) (Code number: 07040). §The generalized MET value of standing with reaching task by ACSM30, 31) (Code number: 07041). ¶The generalized MET value of walking at 4.0 mph by ACSM30, 31) (17220). ¶¶The reported MET value of lying in stroke patients (FAC: 5) by Verschuren25). ¶¶¶The reported MET value of sitting in stroke patients (FAC: 5) by Verschuren25). ¶¶¶¶The reported MET value of standing in stroke patients (FAC: 5) by Verschuren25). ¶¶¶¶¶The reported MET value of standing with reaching task in stroke participants (six-minute walking distance: 291.7 m) by Verschuren25). ¶¶¶¶¶¶The reported MET value in six-minute walking (six-minute walking distance: 308.7 m) by Verschuren25).
The independent t-test showed no significant differences of the estimated METs by accelerometer between participants with subacute stroke and healthy control for the sitting with reaching task and standing with reaching task. The estimated METs by the accelerometer in participants with subacute stroke showed significantly lower values than healthy control for the walking activity. The results are presented at Table 3.

**DISCUSSION**

In this study, we verified the validity of measuring the estimated METs using the Active Style Pro HJA350-IT accelerometer in the people with subacute stroke in comparison with generalized METs reported by ACSM\(^{[30, 31]}\) and previous studies\(^{[25, 26]}\). Based on the results, most of the estimated MET values using the accelerometer in activities of maintaining posture (lying, sitting and standing) showed a tendency to underestimate the MET values compared with generalized MET values by ACSM\(^{[30, 31]}\) and previous studies\(^{[25, 26]}\) and some activities showed values of less than one MET. Our results showed similar results to a previous study reported by Nakano et al.\(^{[33]}\) which stated the estimated MET values using the accelerometer were underestimated in the activities of maintain posture (lying: 0.0 METs, sitting: 0.2 METs and standing: 0.2 METs), although the human body usually metabolizes energy expenditure of at least one MET during the activity of maintaining posture.\(^{[31]}\) The estimated MET values measured by the accelerometer showed values less than one MET. The underestimation of METs in maintaining posture activities may have occurred due to the characteristics of the task which is a motionless activity and the accelerometer depends on bodily movement from participants\(^{[23, 34]}\). The results of this study suggest that the accelerometer is not always adequate to measure the estimated METs in motionless activities such as maintaining lying.

On the other hand, when measuring the estimated METs in sitting with reaching or standing with reaching tasks, the estimated MET values in participants with subacute stroke showed similar values when compared with the estimated MET values in healthy controls, regardless of characteristic differences between subacute stroke and healthy controls. There were no significant differences in the estimated MET values of both groups in comparison with the generalized MET values reported by ACSM\(^{[30, 31]}\). These results suggest that the accelerometer was able to measure the estimated METs during sitting with reaching and standing with reaching tasks with good known-groups validity. Current meta-analysis, which compared the energy expenditure during walking between stroke and healthy controls, has shown that people with stroke expended more energy during walking than those in the healthy control group.\(^{[35]}\) However, recently, Verschuren et al.\(^{[25]}\) has shown interesting findings that energy expenditure during maintaining sitting or standing, in people with stroke, were categorized as sedentary behavior (SB, ≤1.5 METs), but was a classification of intensity of physical activity defined by Pate et al.\(^{[36]}\) and ACSM\(^{[30, 31]}\). These findings suggest that the energy expenditure during relatively low-intensity physical activities, such as non-locomotive activities, may show little difference between stroke patients and healthy people. By contrast, comparisons of the MET values during standing with reaching tasks in participants with subacute stroke and healthy controls showed MET values that were significantly lower than the values reported by Kafri et al.\(^{[20]}\). It could be that these differences were due to the differences in characteristics of the participants between this study and the previous study.\(^{[26]}\) Namely, the 6MD values for participants measured by the previous studies were clearly lower than participants with subacute stroke in this study (this study: 360.3 m, Kafri et al.\(^{[26]}\): 291.7 m). Therefore, it is possible that participants in the previous study reported by Kafri et al.\(^{[26]}\) had lower gait ability and motor function, thus they required more energy expenditure in the standing with reaching task. However, although there were significant differences between this study and previous studies, the estimated MET values showed similar values during the standing activity (this study: 1.8 METs, Kafri et al.\(^{[20]}\): 1.96 METs). To apply a criterion of intensity of physical activity by Pate et al.\(^{[36]}\) (SB: ≤1.5 METs, light-intensity physical activity (LIPA): 1.6–2.9 METs, Moderate-to-vigorous-intensity physical activity (MVPA): ≥3 METs), both the MET values of this study and those of Kafri et al.\(^{[26]}\) were categorized as LIPA. Thus, the accelerometer was probably adequate to measure the intensity-based physical activity of at least 1.6 METs in movement activities.

In addition, the estimated MET values during walking in participants with subacute stroke showed significant differences with the generalized MET values for walking at 4.0 mph by ACSM\(^{[31]}\), reported METs by Verschuren et al.\(^{[25]}\), and the estimated METs in the healthy control group. Gait speed during the testing session is an important factor affecting the estimated MET values and walking at a faster gait speed induces higher estimated MET values.\(^{[31, 37]}\) The relatively wide range of the estimated MET values during walking activity in this study may also suggested that the MET estimation during walking was not as consistent as in the sitting and standing activities. The independent t-test showed no significant differences of the estimated METs by accelerometer between participants with subacute stroke and healthy control for the sitting with reaching task and standing with reaching task. The estimated METs by the accelerometer in participants with subacute stroke showed significantly lower values than healthy control for the walking activity. The results are presented at Table 3.

**Table 3.** Independent t-test comparing estimated METs between stroke and healthy control in movement activities

| Activity                  | Stroke  | Healthy Control |
|---------------------------|---------|-----------------|
| Sitting with reaching task| 1.6 ± 0.3| 1.6 ± 0.3       |
| Standing with reaching task| 1.8 ± 0.2| 1.8 ± 0.1       |
| Walking*                  | 3.8 ± 0.8| 5.7 ± 1.2       |

Values are mean ± standard deviation and are expressed as metabolic equivalents (METs). *Significant differences between groups (p<0.05).
affected by gait speed in the individuals. When compared with subacute stroke participants in this study, ACSM and healthy controls in this study had higher gait speeds and significantly higher MET values during walking and stroke patients in Verschuren et al.25 had lower gait speeds and significantly lower MET values during walking. All the estimated MET values showed higher values as gait speeds increased. Moreover, in the healthy control group, the MET values showed no significant difference compared with the generalized MET values during walking at similar gait speeds by ACSM30,31. Thus, it could be presumed that the accelerometer responded well to measuring the intensity of physical activity during walking according to the gait speed of individuals.

From this data we concluded that the Active Style Pro HJA350-IT accelerometer has the potential to measure the intensity of physical activity during movement activities with good known-groups validity. When applying the criterion of intensity-based physical activity by Pate et al.36, the results were consistent with the estimated MET values of movement activities generalized by ACSM30,31 (sitting with reaching task or standing with reaching task: LIPA, walking: MVPA). However, the accelerometer underestimated the MET values during activities of maintaining posture. Thus, the accelerometer was useful when measuring the intensity of physical activity in movement activities, but was not able to measure motionless activities adequately.

This study had several limitations. First, the sample size of subacute stroke patients was small, and we only studied people with mild gait disorders. Therefore, the results could not be generalized to all people with subacute stroke. Second, we used only sitting with reaching task, standing with reaching task, and walking as the movement activities. The results of this study revealed that the estimated MET values compared with the reported MET values in previous studies, could vary based on the type of movement activities, especially with higher intensity activities using more than three METs. Further study, with larger sample sizes, is required to verify the validity of MET measurement using an accelerometer during various movement activities.

Conflict of interest
None.

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