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Original Article

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

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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 stroke[1, 2] and promoting the improvement of post stroke disabilities[3, 4]. Despite these studies, people have developed an inactive lifestyle at several stages of post-stroke[5, 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 activity[7, 8]. Current systematic review has reported that 11 devices have been investigated for validity of measurement of physical activity in people with stroke[9]. Of these, eight devices have shown good criterion validity of physical activity measurement such as step count[10–13], number of transitions[14], activity count[15], walking duration[16], time of posture[17] or energy expen-

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diture[13, 18] including: SAM, Sensewear Pro 3, Smart Shoe, Wireless Triaxial Accelerometers, IDEEA, Computer Science & Applications Inc. Activity Monitors, PAL 2, and Fitbit Ultra . While many useful devises have recognized utility for physical activity measurement, most previous studies verified validity of measurement of step count only and as an amount of daytime physical activity. According to several clinical guidelines[19–21], when increasing the amount of physical activity in people with stroke, the amount and intensity of physical activity should be considered.

Specifically, National Clinical Guidelines for Stroke[19] have recommended that people with stroke should aim to achieve 150 minutes or more of moderate intensity physical activity per week. In addition, the guidelines advise that physical activity programs for people with stroke should be tailored to the individual after appropriate assessment, starting with low-intensity physical activity and gradually increasing to moderate levels[19]. To implement these physical activity programs for stroke patients, measurement of intensity-based physical activity is also important to assess daytime physical activity and the measurement of step count was not always able to determine the intensity of physical activity. Furthermore, most people with stroke suffer gait difficulties[22], so it is important that the intensity of physical activity measurement was inclusive of activities other than walking, such as sit-to-stand, sitting, or standing in activities of daily living . Thus, we focused on the measurement of intensity-based physical activity such as energy expenditure.

There are few studies verifying the validity of measurements of intensity-based physical activity using an accelerometer through estimating energy expenditure such as metabolic equivalents (MET). Active Style Pro HJA-350IT (OMRON, Kyoto, Japan) is a triaxial accelerometer which was recently developed as an activity monitor. Active Style Pro HJA-350IT has been shown to be highly accurate in MET estimation from a wide range of body motion in activities of daily living in healthy people[23] and has been used to monitor physical activity in people with type 2 diabetes[24]. Active Style Pro HJA-350IT is small, simple to use, and a relatively inexpensive device. It is possible that the Active Style Pro HJA-350IT has potential as a useful measurement device of intensity-based physical activity for patients with subacute stroke in the clinical environment.

To assess the known-groups validity of measurement of estimated METs using Active Style Pro HJA-350IT in people with subacute stroke, we compared the estimated MET values during motor activities in people with subacute stroke with generalized MET values reported in a compendium of physical activities by American College of Sports Medicine (ACSM) and the reported METs in previous studies. In addition, we verified the differences of the estimated MET values during motor activities between the subacute stroke group and healthy control group.

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[25, 26] 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[27]), and independence of walking (assessed with functional ambulation category (FAC)[28], 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[25, 26]. Lying[25] was performed in a relaxed supine position[25]. Sitting participants were asked to maintain the sitting position on a chair without a backrest[25]. Standing participants were asked to maintain a standing position in a fundamental standing position without assistance[25].

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.[26] 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.[26]. To dictate the timing of reaching, digital auditory metronome was used in this study.

A six-minute walking test[29)] 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[25)]. 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/s^2)] 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[30, 31)] and has been used as a reference to monitor lifetime physical activity in affected individuals[32)]. The compendium of physical activities was used as a guide to set the exercise intensity in clinical situations[32)]. Recently, the updated compendium of physical activities provided estimated METs of 821 specific activities[31)]. 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: 07011 for lying; 07021 for sitting; 07040 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 groups in this study.

Additionally, the second reference of MET values were extracted from the estimated MET values using indirect calorimetry in people with stroke based on previous reports as follows: The MET values of lying, sitting and standing were extracted from a report by Verschuren et al.[25)] (the stroke patients could walk at FAC 5), the MET values of standing with reaching task was referenced from a report by Kafri et al.[26)], and the MET values for walking used the MET values during the six-minute walking test in stroke from a report by Verschuren et al.[25)].

Continuous variables were expressed as mean values and standard deviations. Categorical variables were expressed as frequency. The independent t-test was carried out to compare the characteristics (age, BMI, six-minute walking distance, mean gait speed during six-minute walking test) or the estimated MET values during each movement activity (sitting with reaching task, standing with reaching task and walking) between participants in both groups. To verify known-group validity in each activity, one sample t-test was carried out to compare the estimated MET value in participants with subacute stroke with the generalized MET values in the compendium of physical activities by ACSM[30, 31)] or an estimated MET value in people with stroke from previous studies[25, 26)]. 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[30, 31)] or the estimated MET values in people with stroke in previous studies[25, 26)] 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[30, 31)] (lying: 1.0 METs, sitting: 1.3 METs and standing: 1.3 METs). 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[30, 31)] (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 with reaching task: 1.6 ± 0.3 METs and standing with reaching task: 1.7 ± 0.2 METs) and ACSM[30, 31)] (sitting with reaching task: 1.5 METs, standing with reaching task: 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[30, 31)]. 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[30, 31)] (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 (sitting with reaching task: 1.6 ± 0.2 METs and standing with reaching task: 1.8 ± 0.1 METs) and ACSM[30, 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 ACSM[30, 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 studies[25, 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 studies[25, 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/m^2)	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 ($p<0.05$).
Mph: mile per hour; N/A: not applicable.

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

Values are mean ± standard deviation (range), and are expressed as metabolic equivalents (MET).
*Significant differences compared with ACSM ($p<0.05$). †Significant differences compared with previous studies ($p<0.05$).
[a]The generalized MET value of lying quietly by ACSM[30, 31] (Code number: 07011). [b]The generalized MET value of sitting quietly by ACSM[30, 31] (Code number: 07021). [c]The generalized MET value of standing quietly by ACSM[30, 31] (Code number: 07040). [d]The generalized MET value of sitting with reaching task by ACSM[30, 31] (Code number: 07022). [e]The generalized MET value of standing with reaching task by ACSM[30, 31] (Code number: 07041). [f]The generalized MET value of walking at 4.0 mph by ACSM[30, 31] (17220). [g]The reported MET value of lying in stroke patients (FAC: 5) by Verschuren[25]. [h]The reported MET value of sitting in stroke patients (FAC: 5) by Verschuren[25]. [i]The reported MET value of standing in stroke patients (FAC: 5) by Verschuren[25]. [j]The reported MET value of standing with reaching task in stroke participants (six-minute walking distance: 291.7 m) by Kafri[26]. [k]The reported MET value in six-minute walking (six-minute walking distance: 308.7 m) by Verschuren[25].

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.[26]. 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 with stroke in 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.[26]: 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

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

	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 ACSM[30, 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 ACSM[30, 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.

REFERENCES

1) Isabel C, Calvet D, Mas JL: Stroke prevention. Presse Med, 2016, 45: e457–e471. [Medline] [CrossRef]
2) Kernan WN, Ovbiagele B, Black HR, et al. American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, and Council on Peripheral Vascular Disease: Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke, 2014, 45: 2160–2236. [Medline] [CrossRef]
3) Kwakkel G, van Peppen R, Wagenaar RC, et al.: Effects of augmented exercise therapy time after stroke: a meta-analysis. Stroke, 2004, 35: 2529–2539. [Medline] [CrossRef]
4) Askim T, Bernhardt J, Salvesen O, et al.: Physical activity early after stroke and its association to functional outcome 3 months later. J Stroke Cerebrovasc Dis, 2014, 23: e305–e312. [Medline] [CrossRef]
5) Bernhardt J, Dewey H, Thrift A, et al.: Inactive and alone: physical activity within the first 14 days of acute stroke unit care. Stroke, 2004, 35: 1005–1009. [Medline] [CrossRef]
6) English C, Healy GN, Coates A, et al.: Sitting and activity time in people with stroke. Phys Ther, 2016, 96: 193–201. [Medline] [CrossRef]
7) Trost SG, McIver KL, Pate RR: Conducting accelerometer-based activity assessments in field-based research. Med Sci Sports Exerc, 2005, 37: S531–S543. [Medline] [CrossRef]
8) Gebruers N, Vanroy C, Truijen S, et al.: Monitoring of physical activity after stroke: a systematic review of accelerometry-based measures. Arch Phys Med Rehabil, 2010, 91: 288–297. [Medline] [CrossRef]
9) Fini NA, Holland AE, Keating J, et al.: How is physical activity monitored in people following stroke? Disabil Rehabil, 2015, 37: 1717–1731. [Medline] [CrossRef]
10) Fulk GD, Combs SA, Danks KA, et al.: Accuracy of 2 activity monitors in detecting steps in people with stroke and traumatic brain injury. Phys Ther, 2014, 94: 222–229. [Medline] [CrossRef]
11) Mudge S, Stott NS, Walt SE: Criterion validity of the StepWatch Activity Monitor as a measure of walking activity in patients after stroke. Arch Phys Med Rehabil, 2007, 88: 1710–1715. [Medline] [CrossRef]
12) Macko RF, Haeuber E, Shaughnessy M, et al.: Microprocessor-based ambulatory activity monitoring in stroke patients. Med Sci Sports Exerc, 2002, 34: 394–399. [Medline] [CrossRef]
13) Manns PJ, Haennel RG: SenseWear armband and stroke: validity of energy expenditure and step count measurement during walking. Stroke Res Treat, 2012, 2012: 247165. [Medline]
14) Fulk GD, Edgar SR, Bierwirth R, et al.: Identifying activity levels and steps of people with stroke using a novel shoe-based sensor. J Neurol Phys Ther, 2012, 36: 100–107. [Medline] [CrossRef]
15) Alzahrani MA, Ada L, Dean CM: Duration of physical activity is normal but frequency is reduced after stroke: an observational study. J Physiother, 2011, 57: 47–51. [Medline] [CrossRef]
16) Uswatte G, Miltner WH, Foo B, et al.: Objective measurement of functional upper-extremity movement using accelerometer recordings transformed with a threshold filter. Stroke, 2000, 31: 662–667. [Medline] [CrossRef]
17) Kramer SF, Cumming T, Churilov L, et al.: Measuring activity levels at an acute stroke ward: comparing observations to a device. BioMed Res Int, 2013, 2013:

460482. [Medline] [CrossRef]

18) Moore SA, Hallsworth K, Bluck LJ, et al.: Measuring energy expenditure after stroke: validation of a portable device. Stroke, 2012, 43: 1660–1662. [Medline] [CrossRef]

19) Royal College of Physicians: National clinical guideline for stroke, 5th ed. London: The Intercollegiate Stroke Working Party, 2016, pp 108–109.

20) National Stroke Foundation: Clinical guidelines for stroke management 2010. Melbourne: National Stroke Foundation, 2010, p 69.

21) Furie KL, Kasner SE, Adams RJ, et al. American Heart Association Stroke Council, Council on Cardiovascular Nursing, Council on Clinical Cardiology, and Interdisciplinary Council on Quality of Care and Outcomes Research: Guidelines for the prevention of stroke in patients with stroke or transient ischemic attack: a guideline for healthcare professionals from the american heart association/american stroke association. Stroke, 2011, 42: 227–276. [Medline] [CrossRef]

22) Jørgensen HS, Nakayama H, Raaschou HO, et al.: Recovery of walking function in stroke patients: the Copenhagen Stroke Study. Arch Phys Med Rehabil, 1995, 76: 27–32. [Medline] [CrossRef]

23) Ohkawara K, Oshima Y, Hikihara Y, et al.: Real-time estimation of daily physical activity intensity by a triaxial accelerometer and a gravity-removal classification algorithm. Br J Nutr, 2011, 105: 1681–1691. [Medline] [CrossRef]

24) Hamasaki H, Yanai H, Kakei M, et al.: The validity of the non-exercise activity thermogenesis questionnaire evaluated by objectively measured daily physical activity by the triaxial accelerometer. BMC Sports Sci Med Rehabil, 2014, 6: 27. [Medline] [CrossRef]

25) Verschuren O, de Haan F, Mead G, et al.: Characterizing energy expenditure during sedentary behavior after stroke. Arch Phys Med Rehabil, 2016, 97: 232–237. [Medline] [CrossRef]

26) Kafri M, Myslinski MJ, Gade VK, et al.: High metabolic cost and low energy expenditure for typical motor activities among individuals in the chronic phase after stroke. J Neurol Phys Ther, 2014, 38: 226–232. [Medline] [CrossRef]

27) Brunnstrom S: Recovery stages and evaluation procedures. Movement therapy in hemiplegia; a neurophysiological approach. New York: Harper & Row, 1970, pp 34–55.

28) Mehrholz J, Wagner K, Rutte K, et al.: Predictive validity and responsiveness of the functional ambulation category in hemiparetic patients after stroke. Arch Phys Med Rehabil, 2007, 88: 1314–1319. [Medline] [CrossRef]

29) Butland RJ, Pang J, Gross ER, et al.: Two-, six-, and 12-minute walking tests in respiratory disease. Br Med J (Clin Res Ed), 1982, 284: 1607–1608. [Medline] [CrossRef]

30) Ainsworth BE, Haskell WL, Leon AS, et al.: Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc, 1993, 25: 71–80. [Medline] [CrossRef]

31) Ainsworth BE, Haskell WL, Herrmann SD, et al.: 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc, 2011, 43: 1575–1581. [Medline] [CrossRef]

32) Arrigo M, Lüscher TF: Physical activity in patients with coronary artery disease before and after cardiac catheterisation: lack of improvement at 3 months follow-up without cardiac rehabilitation. Kardiov Med, 2007, 10: 317–325.

33) Nakano W, Fukaya T, Shiraishi H, et al.: Validity of accelerometer to measure intensity and kind of physical activity. Med Health Sci Res, 2014, 5: 89–97.

34) Oshima Y, Kawaguchi K, Tanaka S, et al.: Classifying household and locomotive activities using a triaxial accelerometer. Gait Posture, 2010, 31: 370–374. [Medline] [CrossRef]

35) Kramer S, Johnson L, Bernhardt J, et al.: Energy expenditure and cost during walking after stroke: a systematic review. Arch Phys Med Rehabil, 2016, 97: 619–632.e1. [Medline] [CrossRef]

36) Pate RR, O'Neill JR, Lobelo F: The evolving definition of "sedentary". Exerc Sport Sci Rev, 2008, 36: 173–178. [Medline] [CrossRef]

37) Reisman DS, Rudolph KS, Farquhar WB: Influence of speed on walking economy poststroke. Neurorehabil Neural Repair, 2009, 23: 529–534. [Medline] [CrossRef]