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Original Article

Effect of body weight support on predicted locomotive physical activity

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Abstract. [Purpose] This study aimed to evaluate the effect of body weight support with an assistive device on predicted locomotive physical activity measured using triaxial accelerometers in healthy young subjects. [Subjects and Methods] Sixteen healthy subjects aged 21.9 ± 1.1 years walked on a treadmill at speeds of 45 and 55 meters/min under 0%, 10%, 20%, and 30% body weight support conditions. Predicted metabolic equivalents and number of steps were evaluated using triaxial accelerometers. Measured metabolic equivalents and number of steps were evaluated using a metabolic system and observers, respectively. Raw data of synthetic accelerations were also obtained. [Results] Predicted metabolic equivalents and number of steps and raw data of synthetic accelerations decreased with increasing amounts of body weight support. [Conclusion] These findings suggest that accelerometers may underestimate locomotive physical activity with increasing amounts of body weight support using assistive devices. Thus, it is important to consider the amount of body weight support when assessing physical activities in subjects using assistive devices for mobility.

Key words: Triaxial accelerometer, Physical activities, Body weight support

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INTRODUCTION

The number of elderly people using assistive devices is increasing with the growing aging population[1)]. Assistive devices are used to broaden the base of support, improve balance and stability, and allow walkability with body weight support (BWS)[2, 3)]. Assistive device users are more likely to have mobility limitations and less physical activity, compared with non-users[4)]. Inactivity in the elderly has been reported to be associated with an increased risk for mobility disability and mortality[5–8)]. Thus, increasing locomotive physical activities in individuals who walk using assistive devices is important.

Recently, locomotive physical activities have been objectively assessed using triaxial accelerometers[5–10)]. Triaxial accelerometers have shown reliability and validity in evaluating locomotive physical activities in adults[11–13)]; however, several studies have reported inconsistent results[14–19)]. Furthermore, only a few studies have examined the effects of BWS with assistive devices on predicted locomotive physical activities using a triaxial accelerometer[19)]. Therefore, the purpose of this study was to evaluate the effect of BWS with an assistive device on predicted locomotive physical activity using triaxial accelerometers in healthy young subjects.

SUBJECTS AND METHODS

Students from Hiroshima University who did not have any physical impairment that affected ambulation were recruited. Sixteen healthy subjects (8 males and 8 females) aged 21.9 ± 1.1 years with a height of 161.7 ± 8.3 cm, weight of 58.8 ±

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11.5 kg, and body mass index (BMI) of 22.3 ± 2.7 kg/m^2, were enrolled in this study. BMI was calculated as body weight divided by height squared. This study was approved by the ethics committee at Hiroshima University Graduate School of Health Sciences (Approval No. 1516). Written informed consent was obtained from all subjects before the investigation was conducted.

The resting oxygen consumption of the subjects was assessed using a metabolic system (Aero Monitor AE-300; Minato Medical Science Co., Ltd., Osaka, Japan), which is designed to indirectly measure oxygen consumption every 30 seconds. Subjects wore a mask for the metabolic system evaluation, and the resting oxygen consumption was measured in a seated position for 20 minutes. All subjects were prohibited from performing exercise before resting oxygen consumption was measured.

The 0%, 10%, 20%, and 30% BWS conditions were determined before conducting the experiments. First, the cuff of a mercury sphygmomanometer was rolled onto a bilateral handrail and inflated to a pressure of 50 mmHg. The height of the handrail was set at the level of the subject's greater trochanter. Second, the subjects stood on a bathroom scale that was placed on the treadmill (MAT-7000; Fukuda Denshi Co., Ltd., Tokyo, Japan), and distributed their weight through both arms on the cuff while the appropriate pressure for 10%, 20%, and 30% BWS conditions was determined. The bathroom scale was removed and the subjects then walked on the treadmill while distributing their weight through both arms on the cuff to properly adjust the pressure of each BWS condition while looking at the meter of the sphygmomanometer. In the 0% BWS condition, the subjects walked on the treadmill while placing their hands on the cuff without any BWS.

After the BWS conditions were determined, the subjects wore two accelerometers (Active Style Pro HJA-750C; Omron Healthcare Co., Ltd., Kyoto, Japan and ActivTracer AC-301A; GMS Co., Ltd., Tokyo, Japan) on a belt that was placed at the bilateral anterior superior iliac spine, and then walked on the treadmill at speeds of 55 and 45 m/min for 4 minutes under the four BWS conditions: 0%, 10%, 20%, and 30%. The walking speed of 55 m/min was used based on previous studies[12, 19)] that determined that the accelerometer (Active Style Pro HJA-750C) provided a precise measure of locomotive physical activities at a speed greater than 55 m/min. The walking speed of 45 m/min was chosen based on several studies that reported that the gait speed in older adults who had low physical function was approximately 45 m/min[20, 21)]. Furthermore, preliminary studies showed no significant difference between predicted and measured metabolic equivalents (METs) and between predicted and measured number of steps in the 0% BWS condition for both walking speeds. All subjects walked under randomized four BWS conditions at speeds of 55 or 45 m/min randomly chosen, and then they performed BWS walking at the remaining speed. Subjects were instructed to rest in a seated position for at least 5 minutes between each trial. Predicted METs and predicted number of steps were evaluated using the Active Style Pro accelerometer, which was programmed to record at 10-second epochs. Oxygen consumption during walking was measured using the metabolic system. METs was calculated from oxygen consumption during walking divided by resting oxygen consumption. Measured number of steps was recorded by observers using hand counters. Synthetic accelerations were obtained from the ActivTracer accelerometer every 0.2 seconds. The accuracy of predicted METs and number of steps from the accelerometer were calculated using the following formulas:

Accuracy of predicted METs=(predicted METs/measured METs) ×100 and

Accuracy of predicted numbers of steps=(predicted numbers of steps/measured numbers of steps) ×100.

All data are presented as mean ± standard deviation. The data from the last 10 minutes of measured resting oxygen consumption were used for statistical analysis. METs, number of steps, and synthetic accelerations from the last 2 minutes of each walking condition were used for statistical analysis. Wilcoxon signed-rank test was used to compare differences between predicted and measured METs, as well as predicted and measured number of steps. The Wilcoxon signed-rank test was also used to compare the accuracy of the predicted METs and predicted number of steps between the walking speeds (55 vs. 45 m/min), separately. The data for METs, number of steps, accuracy of predicted METs, accuracy of predicted number of steps, and synthetic accelerations for all BWS conditions were evaluated using variance analyses, followed by Dunnett's test, for comparison to the 0% BWS condition. A $p<0.05$ was considered statistically significant. JMP® 12 (SAS Institute Inc., Cary, NC, USA) was used for statistical analysis.

RESULTS

The mean height of the handrail was 80.9 ± 4.9 cm. The predicted METs were significantly lower than the measured METs in the 10%, 20%, and 30% BWS conditions at a speed of 55 m/min (p=0.04, p=0.009, and p=0.002, respectively), as well as in the 20% and 30% BWS conditions at a speed of 45 m/min (p=0.02 and p<0.001, respectively) (Table 1). The predicted METs were lower with greater amount of BWS. The predicted METs in the 20% and 30% BWS conditions were significantly lower than those in the 0% BWS condition at a speed of 55 m/min (p=0.04 and p<0.001, respectively). Similarly, the predicted METs in the 30% BWS condition were significantly lower than the 0% BWS condition at a speed of 45 m/min (p<0.001). Conversely, there were no significant effects of BWS condition on measured METs for any walking speed.

The predicted number of steps was significantly lower than the measured number of steps in the 30% BWS condition completed at a speed of 55 m/min (p=0.01), as well as in the 10%, 20%, and 30% BWS conditions at a speed of 45 m/min (p=0.003, p<0.001, and p=0.001, respectively) (Table 2). The predicted number of steps was lower with a greater amount of BWS. Furthermore, the predicted number of steps in the 30% BWS condition were significantly lower, compared with the 0% BWS condition at a speed of 45 m/min (p=0.04). No significant effects of BWS condition on the measured number of

Table 1. Comparison between predicted and measured metabolic equivalents

Walking speed (m/min)	BWS condition	Predicted METs	Measured METs
55	0%	3.1 ± 0.2	3.1 ± 0.4
	10%	3.0 ± 0.3	3.2 ± 0.3*
	20%	2.9 ± 0.2**	3.3 ± 0.4*
	30%	2.7 ± 0.3**	3.3 ± 0.4*
45	0%	2.7 ± 0.1	2.7 ± 0.3
	10%	2.7 ± 0.2	2.9 ± 0.3
	20%	2.6 ± 0.2	2.9 ± 0.4*
	30%	2.5 ± 0.2**	3.0 ± 0.4*

Data are presented as mean ± standard deviation. METs: metabolic equivalents; BWS: body weight support. *Significant difference between predicted and measured METs (p<0.05). **Significant difference, compared with predicted METs in the 0% BWS condition (p<0.05).

Table 2. Comparison between predicted and measured number of steps

Walking speed (m/min)	BWS condition	Predicted number of steps	Measured number of steps
55	0%	203.3 ± 20.7	203.1 ± 20.2
	10%	202.9 ± 20.1	206.0 ± 19.8
	20%	203.1 ± 27.4	208.5 ± 21.9
	30%	185.1 ± 49.2	209.4 ± 22.9*
45	0%	175.0 ± 30.8	183.6 ± 18.8
	10%	157.3 ± 48.6	187.4 ± 23.2*
	20%	146.3 ± 60.7	189.0 ± 23.1*
	30%	128.6 ± 64.4**	187.9 ± 25.2*

Data are presented as mean ± standard deviation. BWS: body weight support. *Significant difference between predicted and measured number of steps (p<0.05). **Significant difference, compared with predicted numbers of steps in the 0% BWS condition (p<0.05).

Table 3. Accuracy of predicted metabolic equivalents and predicted number of steps by walking speed

	55 m/min	45 m/min
Accuracy of predicted METs (%)		
0% BWS	101.3 ± 13.2	101.6 ± 14.4
10% BWS	93.7 ± 11.6	94.7 ± 14.0
20% BWS	89.3 ± 14.1	91.0 ± 15.4
30% BWS	84.7 ± 15.8**	83.9 ± 13.0**
Accuracy of predicted number of steps (%)		
0% BWS	100.1 ± 0.6	95.3 ± 13.0
10% BWS	98.6 ± 4.3	83.4 ± 24.1*
20% BWS	97.3 ± 7.1	75.8 ± 28.8*
30% BWS	87.8 ± 20.1**	67.1 ± 33.2*,**

Data are presented as mean ± standard deviation. METs: metabolice quivalents; BWS: body weight support. *Significant difference in accuracy between walking speeds (p<0.05). **Significant difference, compared with accuracy of predicted METs or numbers of steps in the 0% BWS condition (p<0.05).

Table 4. Raw data of synthetic accelerations by walking speed

	55 m/min	45 m/min
Raw data of synthetic accelerations (mG)		
0% BWS	270.3 ± 28.2	215.3 ± 21.3
10% BWS	255.4 ± 34.0	206.2 ± 25.1*
20% BWS	236.5 ± 30.8**	196.0 ± 29.2*
30% BWS	219.0 ± 37.4**	180.1 ± 19.5*,**

Data are presented as mean ± standard deviation. BWS: body weight support. *Significant difference in synthetic accelerations between walking speeds (p<0.05). **Significant difference, compared with synthetic acceleration in the 0% BWS condition (p<0.05).

steps were observed at any walking speed.

The accuracy of predicted METs (45 m/min, p=0.01 and 55 m/min, p=0.01) and predicted number of steps (45 m/min, p=0.01 and 55 m/min, p=0.04) in the 30% BWS condition was significantly lower than those in the 0% BWS condition for both walking speeds (Table 3). Moreover, the accuracy of predicted number of steps at 45 m/min was significantly lower than that at 55 m/min in the 10%, 20%, and 30% BWS conditions (p=0.005, p<0.0001, and p=0.02, respectively). Significant differences were not found between the accuracy of predicted METs at 45 m/min and that at 55 m/min for all BWS conditions.

The raw data of synthetic accelerations were lower with greater amount of BWS (Table 4). The raw data of synthetic accelerations in the 20% and 30% BWS conditions were significantly lower than those in the 0% BWS condition at a speed of 55 m/min (p=0.01 and p<0.001, respectively). Additionally, the raw data of synthetic accelerations in the 30% BWS condition were significantly lower than those in the 0% BWS condition at a speed of 45 m/min (p<0.001). Furthermore, the raw data of synthetic accelerations at 45 m/min were significantly lower than those at 55 m/min in the 10%, 20%, and 30% BWS conditions.

DISCUSSION

This study investigated the effect of BWS with an assistive device on locomotive physical activity that was predicted using accelerometers in healthy young subjects. The predicted METs and number of steps and the raw data of synthetic accelerations were lower with greater amount of BWS. It was suggested that the accelerometer may underestimate locomotive physical activity in assistive device users.

Body weight-supported walking with assistive devices may lead to decreased accelerations, thereby causing underestimation of locomotive physical activities assessed using a triaxial accelerometer. A triaxial accelerometer predicts locomotive physical activities from accelerations[11, 12]. Predicted METs are estimated by substituting modified synthetic accelerations into a specific equation. Predicted number of steps is counted when the size of the acceleration amplitude during walking is greater than the predetermined threshold[22]. Previous studies have shown that body weight-supported walking using a harness or anti-gravity treadmill decreased accelerations with increases in BWS amount[23, 24]. In this study, accelerations during walking were lower with increased amount of BWS, which may have led to the lower predicted METs and number of steps.

The predicted number of steps may be affected by walking speed and the amount of BWS. Previous studies have demonstrated that pedometers and accelerometers underestimate the number of steps as the walking speed decreases[15–19], and accelerations during walking greatly decrease as the walking speed decreases[19]. In this study, the raw data of synthetic accelerations and the accuracy of predicted number of steps at 45 m/min were significantly lower than those at 55 m/min for the 10%, 20%, and 30% BWS conditions. However, no significant differences were found between the accuracy of predicted METs at 45 m/min and those at 55 m/min for all BWS conditions. On the basis of these results, the predicted number of steps was likely associated with the synthetic accelerations that were affected by walking speed and the amount of BWS.

To our knowledge, this study is the first to examine the effects of several levels of BWS with an assistive device on locomotive physical activity that was predicted using a triaxial accelerometer in the same subjects. It was indicated that locomotive physical activity, which was assessed using an accelerometer, was lower with increasing amount of BWS. Park et al. reported that absolute acceleration and predicted METs and number of steps measured using accelerometers in older adults who were using assistive devices were lower than those in healthy older adults[19]. The researchers also reported that the mean usual gait speed in older adults using assistive devices was lower than those in healthy older adults (30.3 vs. 64.2 m/min, respectively). To clarify the effects of BWS with assistive devices on locomotive physical activities, subjects with or without assistive devices should walk at the same speed. Other reports also examined the accuracy of pedometers and accelerometers in older adults, including cane users; however, these reports did not focus solely on the effects of BWS with assistive devices[14–16].

There were some limitations in this study. First, the sample size was small (n=16), which may diminish the significance of the results of this study. Second, the walking posture of each BWS condition was different from actual walking posture. Third, these results from young healthy subjects may not be applicable to elderly patients using assistive devices because of different characteristics, such as body composition and body movement. In addition, elderly patients may require more oxygen consumption during walking than young subjects[25]. Therefore, further studies are needed to verify the accuracy of a triaxial accelerometer in the elderly under the same conditions. Fourth, subjects completed each walking condition on a treadmill, and not in a free environment. The energy expenditure of walking on a treadmill is known to be different from that of walking on the ground[26]. Finally, this study was conducted with only hip-worn accelerometers; therefore, using other types of accelerometers may affect the results.

In conclusion, it was found that accelerometers underestimated locomotive physical activity with increasing amounts of BWS using an assistive device. This study may make a significant contribution to the literature because it provides evidence regarding the use of accelerometry in evaluating locomotive physical activity in individuals who use assistive devices for mobility.

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Conflict of interest

There are no conflicts of interest to declare.

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