Original Article

Effects of Age and Body Mass Index on Accuracy of Simple Moderate Vigorous Physical Activity Monitor Under Controlled Condition

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Abstract

Purpose: The purpose of the present investigation was to examine the validity and reliability of the simple moderate to vigorous physical activity (MVPA) monitor (NL-1000; NEWLIFESTYLES, MO) during treadmill walking and running.
Methods: A total of 70 men and women, between 22 to 76 years of age, participated in the present investigation. Subjects continuously wore the NL-1000 device on their waist. The NL-1000 calculated the time spent in MVPA corresponding to > 3 METs. All subjects walked at speeds of 40 to 115 m•min^{-1} and ran at a speed of 130 m•min^{-1} on a motor driven treadmill for four minutes. Furthermore, eight of all subjects performed a second experiment in order to assess the reliability of NL-1000.
Results: The MVPA measured by the NL-1000 (MVPAped) significantly increased at a walking at the speed of faster than 85 m•min^{-1} ($p < 0.05$). Of the actual exercise time, MVPAped corresponded to > 90% of the actual exercise time in > 85 m•min^{-1} or faster speed. A multiple regression analysis showed that gender, body mass index, and age did not significantly affect the accuracy of MVPAped, and the treadmill speed came out significant parameter of MVPAped. The MVPAped did not differ significantly within the first and second experiment, furthermore, the results correlated significantly (r = 0.956, $p < 0.001$).
Conclusion: These results indicate that simple MVPA monitor would be a valid instrument to during the treadmill walking and running.

KEY WORDS: Aging, Accelerometer, Pedometer, Motion sensor, Public health

Introduction

The moderate to vigorous intensity physical activity (MVPA) has been considered in the prevention and treatment of various public health diseases [1-6]. Current findings suggest that the incidence of type 2 diabetes and cardiovascular events can be reduced by increased MVPA [2,3,5]. Furthermore, several consensus statements recommend MVPA in order to obtain the health benefits [1,4,6]. The American College of Sports Medicine and the American Heart Association [4] recommended for all healthy adults aged 18 to 65 yr to participate MVPA for a minimum of 30 min a day, 5 days a week or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week to promote and maintain health. Therefore, the accurate and practical assessment of the time spent in MVPA has been required.

The doubly labeled water method and the room calorimeter method are the most accurate and reliable assessments of physical activity (PA) [7]. Although these methods are considered the gold standard for the assessment of total energy expenditure, neither of them can assess the time spent in MVPA in free-living conditions. Furthermore, the accuracy and reliability of the questioners and the dairy methods are sometimes doubtful. The PA levels determined by the objective assessments significantly associated with the health outcomes, but self reported PA levels did not [8,9]. Pedometers cannot assess the intensity of PA, whereas pedometers are inexpensive and user-friendly assessment of PA [10-18]. Accelerometers have been considered an objective assessment of the time spent in MVPA [19-22]. Previous investigations have demonstrated that the MVPA assessed by an accelerometer correlated well with that assessed by the indirect-calorimeter and the room calorimeter [20]. However, general accelerometers are expensive, and require the effort for data analysis. Therefore, the use of accelerometers is limited to the research purpose.

A new type of activity monitor (NL-1000, NEWLIFESTYLES, MO) based on accelerometry has been developed that can simply assess the amount of MVPA. Although previous accelerometers require data analysis via a computer in order to obtain MVPA [19-22], this device can directly display the time spent in MVPA. Furthermore, NL-1000 is a less expensive instrument than the previous model accelerometers. Therefore, this activity monitor

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could provide a helpful assessment of MVPA for researchers as well as exercise practitioners.

Limited information has been known about the validity of this simple activity monitor for assessing the time for MVPA. The Lifecorder determined MVPA in same manner with NL-1000. Although we previously described the validity of the time for MVPA by the Lifecorder using an indirect calorimeter, the subjects of the previous investigation were limited to the 10 young men [20]. McClain et al. [23] also showed that NL-1000 was a reasonable estimates of free-living MVPA in young to middle-aged adults. Since the accuracy of activity monitor was associated with the age [10,13] and body mass index [12,18], the validity of MVPA assessed by NL-1000 (MVPAped) also should be evaluated in heterogeneous individuals.

Thus the purpose of this study is therefore to examine the validity of a simple and user-friendly activity monitor for assessing the time spent in MVPA during treadmill walking and running.

Methods

Subjects

A total of 70 healthy individuals participated in this investigation. The characteristics of the subjects are shown in *Table 1*. None of the subjects had any disorder in their lower extremities, and were free from any chronic heart disease. After explaining the study design and requirements to all participants, all subjects signed an informed consent form. All procedure of the present investigation were approved by the ethics committee of the Juntendo University.

Exercise Protocol

All subject performed a graded exercise test using a motor driven treadmill (Nishikawatekko, Sumida-ku, Tokyo). The subjects walked at the speed of 40, 55, 70, 85, 100 and 115 m•min^{-1}, and ran at the speed of 130 m•min^{-1}. The duration of each stage was 4 minutes, and each grade was separated by a 1 min rest period in order to evaluate the time of MVPA assessed by NL-1000. Furthermore, 8 of these subjects performed these procedures 2 times within 14 days in order to determine the reproducibility of the NL-1000.

Pedometer futures

During the course of the present investigation, NL-1000 was placed at on the left anterior mid-line of the thigh on the waist band of the participant's clothing. The NL-1000 is small and light and is equipped with a piezo-electric accelerometer. The NL-1000 detects the accelerations ranging between 0.06 to 1.94 G at 32 Hz. The NL-1000 divided physical activity into one of 10 categories (0 and 1 to 9) every 4 sec according to the size and frequency of accelerations. Based on the instruction manual as well as a previous finding [20], the NL-1000 device was set to display the time spent in physical activity corresponding to levels 4 to 9 of these activity levels. These categories are defined to be MVPA corresponding to > 3.6 METs. Although NL-1000 can assess the number of steps in addition to the MVPA, the current study focused on the accuracy for the assessment of MVPA.

The values are expressed as the mean with standard deviation. The subjects were categorized into subgroups according to age (< 40 yr., 40 to 64 years, or > 64 years) and body mass index (< 25 kg•m^{-2} or ≥ 25 kg•m^{-2}). The differences in the physical characteristics and the accuracy of NL-1000 within the same sex were determined by the un-paired *t*-test. The differences in the physical characteristics within the subgroups were determined by one factor ANOVA and a post-hoc analysis (Scheffe). Furthermore, the relationship regarding the accuracy of NL-1000 with the treadmill speed was determined by a repeated-measures ANOVA and post hoc analysis (Scheffe). Two-factor repeated-measures ANOVA was used to determine the effects of the body mass index or age on the accuracy of MVPAped. The relationship of the accuracy of MVPAped with age, height, weight, body mass index as well as the treadmill speed was determined by a step-wise regression analysis. Finally, the Bland-Altman plots were used to show the distribution of individual differences between the first and second experiment. The difference between the first and second experiment was plotted against the mean of the two instruments with the limits of agreement (mean ± 2SD of difference). The correlation between the two variables was assessed by the Pearson correlation coefficient (r). All the statistical analyses were done using the Stat View software program (SAS Institute, Cary, NC). A *p*-value of < 0.05 was considered to be statistically significant for all analyses.

Table 1 Characteristics of subjects

	Women			Men		
	22 to 39 yr. N = 9	40 to 64 yr. N = 31	65 to 76 yr. N = 6	22 to 39 yr. N = 5	40 to 64 yr. N = 10	65 to 74 yr. N = 9
Age (years)	29 ± 5 *	53 ± 7 *‡	68 ± 3 *‡§	22 ± 2	59 ± 6 ‡	70 ± 3 ‡§
Height (cm)	161 ± 5 *	156 ± 5 *‡	154 ± 4 *‡§	169 ± 5	167 ± 5	166 ± 4 ‡
Weight (kg)	55 ± 7 *	56 ± 9 *	55 ± 10*	67 ± 4	64 ± 7	69 ± 8 §
Body mass index (kg•m^{-2})	21 ± 2 *	23 ± 4 *‡	23 ± 4 *‡	23 ± 2	23 ± 3	25 ± 3 ‡§

Data are expressed as mean±standard deviation.
*Significantly different in comparison to the men (*p* < 0.05),
‡Significantly different in comparison to the younger individuals within same sex (*p* < 0.05),
§Significantly different in comparison to the middle-aged individuals within same sex (*p* < 0.05).

Results

Table 1 shows the characteristics of the subjects. The height, body weight and body mass index significantly differed between men and women within the same age categories ($p < 0.05$), except body mass index in the middle-age (40 to 64 years) to older (> 65 years) group. Furthermore, the height, body weight and body mass index differed significantly across the age categories within the same gender.

Table 2 shows the MET value, MVPAped, and its accuracy. Since the MVPAped and the accuracy did not significantly differ between men and women at all speeds, the data was not divided across the gender. There was a significant effect of treadmill speed on the MVPAped and its accuracy ($p < 0.001$, Table 1). The MVPAped significantly increased from the speed of 70 m•min^{-1} in comparison to that at the previous lower speed ($p < 0.05$). Furthermore, the MVPAped did not changed significantly at 85 m•min^{-1} or faster treadmill speed, while the treadmill speed increased. Of the actual exercise time (240 sec), the MVPAped corresponded to 53 ± 35% at 70 m•min^{-1} and 91 ± 16% at 85 m•min^{-1}, thereafter; it was maintained above 99% at 100 m•min^{-1} or faster treadmill speed.

Fig. 1 shows the effects of age and treadmill speed on the accuracy of MVPAped. The results of two factors repeated measures ANOVA indicated that both age ($p = 0.0413$) and the treadmill speed ($p < 0.001$) had a significant effect on the accuracy of MVPAped. However, the interaction of these variables was not statistically significant ($p = 0.751$). Moreover, Fig. 2 showed that the effects of body mass index and treadmill speed on the accuracy of MVPAped. The results of two-factor repeated measures ANOVA indicated that the effects of body mass index on the accuracy of MVPAped just barely failed to achieve statistical significance ($p = 0.073$), while the effects of treadmill speed were significant ($p < 0.001$). In addition, the interaction of these two variables was not statistically significant ($p = 0.859$). Moreover, a multiple stepwise regression analysis including age, BMI and treadmill speed revealed that single parameter of treadmill speed came out significant parameter of the MVPAped ($R^2 = 0.706$, $p < 0.001$).

Fig. 3 shows the correlation and the Bland-Altman plots between the first and second test. The MVPAped between the two tests significantly correlated (r = 0.991, $p < 0.001$), but there was no significant difference between the two scores. The mean of the difference within the two measurements was –2.34 sec, and the upper and lower agreement was –31.2 sec and 26.5 sec.

Table 2   Time for moderate to vigorous intensity physical activity via NL-1000 during treadmill walking and running

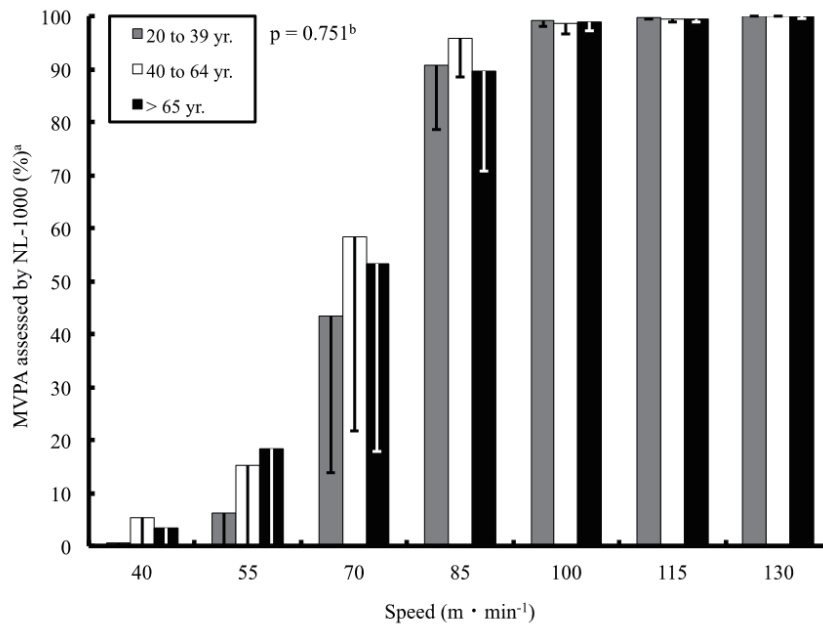|		METs[a]	NL-1000	
			MVPA (sec)[b]	%[c]
Walking	40 m•min^{-1}	2.1	8 ± 32	3 ± 13
	55 m•min^{-1}	2.6	37 ± 58	16 ± 24
	70 m•min^{-1}	3	127 ± 83 †	53 ± 35 †
	85 m•min^{-1}	3.4	219 ± 38 †	91 ± 16†
	100 m•min^{-1}	3.9	237 ± 4	99 ± 2
	115 m•min^{-1}	4.3	239 ± 2	100 ± 1
Running	130 m•min^{-1}	8.4	240 ± 1	100 ± 0 †

Data are expressed as mean±standard deviation.
[a] Metabolic equivalents estimated by the previous finding (1),
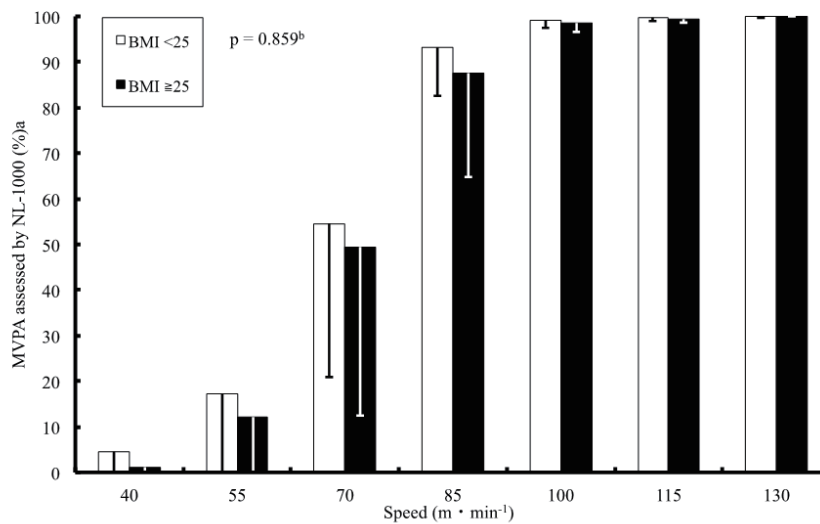[b] Moderate to vigorous intensity physical activity assessed by an NL-1000,
[c] proportion of moderate to vigorous intensity physical activity assessed by an NL-1000 in actual exercise time (240 sec).
†Siginifically different incomapridon to that at the preliminarly speed ($p < 0.05$).

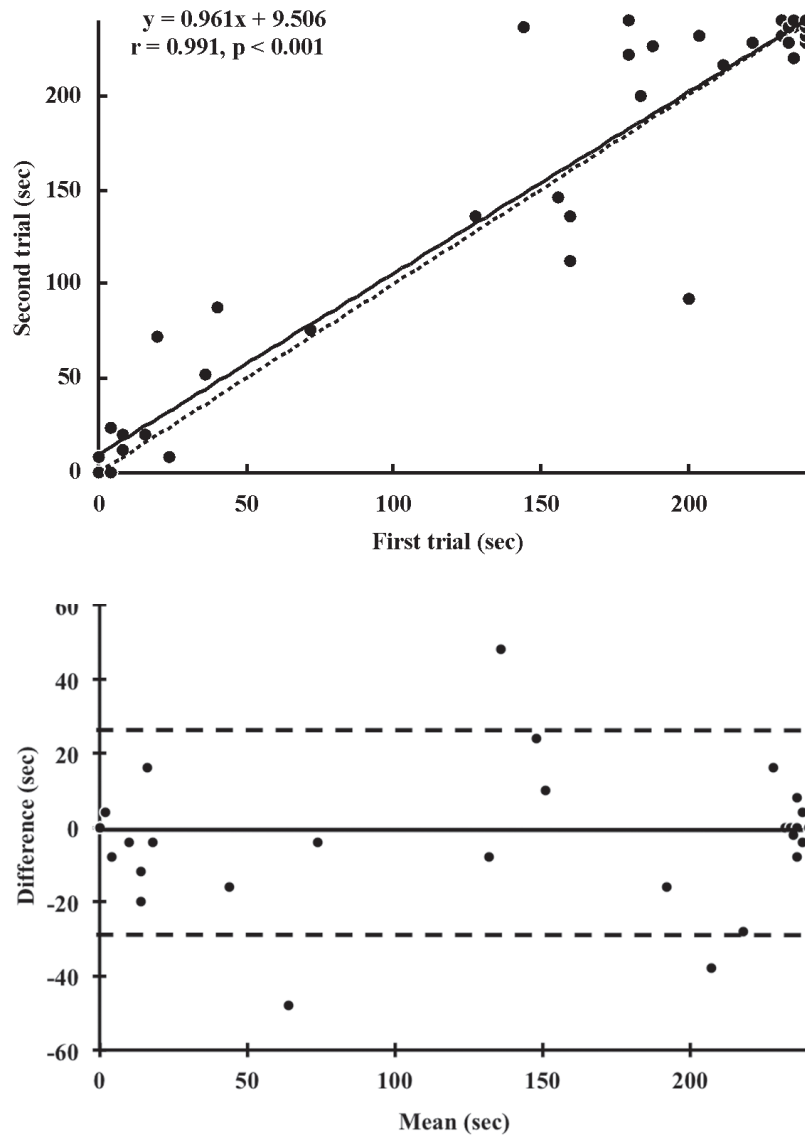**Fig. 1.** **Effects of age and treadmill speed on the accuracy of NL-1000 for assessing moderate to vigorous intensity physical activity**
a Proportion of moderate to vigorous intensity physical activity assessed by an NL-1000 in actual exercise time (240 s).
b The *p*-value indicates the results of two factors repeated measures ANOVA (Speed and Age).

Fig. 2. **Effects of the body mass index and the treadmill speed on the accuracy of NL-1000 for assessing moderate to vigorous intensity physical activity**
a Proportion of moderate to vigorous intensity physical activity assessed by an NL-1000 in actual exercise time (240 s).
b The *p*-value indicates the results of two factors repeated measures ANOVA (Speed and body mass index).

y = 0.961x + 9.506
r = 0.991, p < 0.001

Fig. 3. **The test-retest reliability of NL-1000 for assessing moderate to vigorous intensity physical activity**
The upper graph illustrates the correlation of two measurements. The dashed line is the identity line (y=x).
The lower graph illustrates the Bland-Altman plots for the two measurements. The solid horizontal line shows the mean error score. The dashed lines show the 95% confidence intervals of the individual observations.

Discussion

The present investigation studied the validity of simple practical MVPA monitor in 70 healthy individuals participating under treadmill walking and running. The main finding of the present investigation is that the simple activity monitor can assess the actual time for MVPA (MVPAact) within 10% of underestimation during a horizontal walking at the speed of 85 m•min^{-1} or faster speed corresponding to > 3.4 METs, whereas MVPAped underestimated the MVPAact in a horizontal walking at the speed of 70 m•min^{-1} corresponding to 3 METs. Furthermore, the accuracy of MVPAped was not associated with age or body mass index. These findings indicate that the time for MVPAped will accurately reflect the MVPAact for horizontal walking in healthy adults, and an accurate assessment will be guaranteed during horizontal walking at 85 m•min^{-1} or faster speeds corresponding to 3.4 METs.

As shown in **Table 2**, the MVPAped significantly increased from 70 m•min^{-1} corresponding to 3 METs, and half of the MVPAact was defined as MVPAped at this speed. Furthermore, the almost all of the MVPAact was included in MVPAped at speeds of 85 m•min^{-1} or faster (3.4 METs). These results were consistent with the previous validation studies [20,22]. A previous investigation [20] showed that the same type of accelerometer defined PA corresponding to > 3.6 METs was defined as MVPA, furthermore, ±0.46 METs of the standard error of estimate was found for the relationship. Similarly, the present investigation showed that NL-1000 could detect almost all of MVPAact during horizontal walking at the speed of 85 m•min^{-1} or faster corresponding to > 3.4 METs. Additionally, the present investigation found NL-1000 had a good test-retest reliability.

Previous investigations demonstrated the accelerometers to be able to accurately assess the time for MVPA. Kumhahara *et al.* [20] suggested that the standard error of estimation in the Lifecorder was smaller in comparison to a classical uniaxial accelerometer. Furthermore, McClain *et al.* [22] demonstrated the MVPA, as assessed by the Lifecorder and the Actigraph using Freedson's equation did not differ significantly under free-living conditions. Since NL-1000 and the Lifecorder evaluate the MVPA in the same manor, NL-1000 is considered to a valid assessment of the MVPA. Additionally, in the present investigation, the MVPAped was not associated with treadmill speed rather than sex, age or body mass index. The recent studies [10,12,15,18] examined the effects of age and body mass index on the pedometer accuracy. These studies suggested that the accuracy of a spring-levered pedometer decreased in older individuals and/or obese individuals, but the accuracy of a piezo-electric pedometer did not [12,15]. Although the number of steps and the time for MVPA are determined by different algorisms, the results of the present investigation were supported by these previous findings.

There are several limitations in regard to the results shown in the present investigation. First, it is unclear whether the MVPAped accurately reflect MVPAact under free-living conditions. Second, the participants in the present investigation were limited to the individuals over 20 years of age and individuals without severe obesity. Additionally, the sample size of the present investigation associate with older subjects and female subjects is not enough, whereas multiple stepwise regression analysis showed single parameter of treadmill speed came out significant parameter of the MVPAped. A previous investigation [21] suggested that higher intensity categories were suitable for assessing MVPA for children in comparison to adults. Therefore, the accuracy of MVPAped remains unclear in children and/or the obese individuals whose body mass index exceeds 30.

In summary, the present study demonstrated that the simple expensive activity monitor can assess the time for MVPA within 10% of the underestimation during horizontal walking at the speed of 85 m•min^{-1} or faster corresponding to > 3.4 METs. Furthermore, the accuracy of the MVPAped was not associated with the age or body mass index. These findings indicate that the time for MVPAped will accurately reflect the MVPAact during horizontal walking in healthy adults including older individuals. The clinical significance of the simple MVPA monitor remains unclear.

Acknowledgements

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