Accuracy of step count of five pedometers under free-living conditions

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Abstract

The purpose of this study was to investigate accuracy of step count of the 5 pedometers under free-living conditions. Seven young subjects wore two pedometers for 5 days, excluding bath and sleep time. One of the two pedometers, the Lifecorder (LC, Suzuken Co.) was worn on the right side of the waist for 5 days as a criterion. Each subject wore one of the five pedometers randomly for one day each. The 3 waist-type pedometers (EC-200; Yamasa tokei, Welsupport; Nipro Co., HJA-350IT; Omron Co.) were worn on the left side of the waist. A wrist-type pedometer (HK-800; Yamasa tokei) was worn on the right wrist. A pocket-in-type pedometer (HJ-710; Omron Co.) was kept in the left pocket of the subject's trousers. The daily steps of the LC were 6,123+/-2,027 counts (range: 1,974-15,815). Comparing with LC, a significant difference in the daily steps were found using the HJ-710 ($p<0.001$) and the HJA-350IT ($p<0.05$). We predicted that the accuracy of HJ-710 was low because the pocket-in pedometer moved in the pocket. However, it is unclear why the daily steps measured by HJA-350IT were significantly low. We concluded that a high accurate pedometer must be used to measure daily physical activity.

Key words : daily steps, pedometer, physical activity
2010.11.17 accept

Introduction

The level of daily physical activity has been measured by a pedometer or an accelerometer [1-7]. Schneider et al.[4] reported that the Lifecorder Ex (LC; Suzuken Co.) was useful for measuring daily steps as daily physical activity. LC has an acceleration-sensor and can estimate the intensity of physical activities. Most pedometers are worn on the waist. Recently, the wrist type or pocket-in type pedometer has been developed. However it is not known accuracy of the newly designed pedometers. Validity of HJ-112 (Omron Co.), a pocket-in pedometer, was reported by Hasson et al. [5]. During treadmill walking, the validity of step counts measured by HJ-112 was high; however, during a free-living condition, it may not always be highly accurate under free-living conditions. The purpose of this study was to estimate accuracy of step count of the 5 pedometers under free-living conditions.

Methods

Subjects

Seven young subjects (age, 20.4+/-0.5 years; mean+/-SD) participated in this study. The subjects did not have a regular exercise habit, such as walking and jogging. All subjects were given a sufficient explanation regarding the study, and subsequently their informed consent was obtained.

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Measuring the daily steps

All subjects wore two pedometers for 5 days, excluding bath and sleep time. One of the two pedometers, LC was worn on the right side of the waist for 5 days as a criterion. Accuracy of LC is set by the Japanese Industrial Standards. The error of counts is less than 3%. Validity of LC has been reported in previous studies [6, 7].

Each subject wore one of the five pedometers randomly for one day each. The 3 waist-type pedometers (EC-200, Yamasa tokei ; Welsupport, Nipro Co.; HJA-350IT, Omron Co.) were worn on the left side of the waist. The EC-200 pedometer has the same structure as the Yamax SW-200 pedometer [4]. The wrist-type pedometer (HK-800, Yamasa tokei) was worn on the right wrist. The pocket-in pedometer (HJ-710, Omron Co.) was kept in the left pocket of trousers. HJ-710 has the same structure as HJ-112 pedometer [5]. All pedometers were shown in Fig.1. The daily steps of the EC-200 and HK-800 were recorded on a sheet by the subjects, because those pedometers do not have a memory function of the daily steps. The other pedometers were collected, and then the daily steps were downloaded to a computer and analyzed using the each software.

Statistical analysis

The comparison of the daily steps between 5 pedometers and LC was conducted using paired *t*-test. The Bland and Altman plots were constructed for each pedometer to illustrate the distribution of the individual error scores around zero. All analyses were done with StatView 5.0J for Windows (SAS Institute Inc.). Statistical difference was set at $P<0.05$.

Results

The daily steps of LC were 6,123+/-2,027 counts, (rage, 1,974-15,815). The difference in the total daily steps between the 5 pedometers and a criterion pedometer was shown in Table 1. Significant differences in the daily steps were found in HJ-710 ($p<0.001$) and HJA-350IT ($p<0.05$).

Fig. 2 showed the Bland-Altman plots for 5 pedometers and LC. In the waist-type 3 pedometers (EC-200, HJA-350IT, HJ-710), the distribution of the individual error in daily steps was plotted above each zero line. All pedometers appeared to underestimate the total daily steps.

Discussion

In the present study, we estimated the accuracy of the daily steps of 5 pedometers, 3-type (waist, wrist, and pocket-in), under free-living conditions. Two (HJ-710 and HJA-350IT) of the 5 pedometers significantly underestimated the total daily steps. The HJ-710 has the same structure as the HJ-112 pedometer. The accuracy of HJ-112 pedometer was high during treadmill walking [5]. In the present study, however, the HJ-710 might be moved in the pocket. When a pedometer is not fixed on the body, the body acceleration can not be measure accurately. Therefore, the HJ-710 might not be able to accurately measure daily steps.

Although three pedometers (Welsupport, HJA-350IT and HJ-710) have a build in acceleration-sensor, the average daily steps appeared to be underestimated (Table 1). A pedometer with a build-in acceleration-sensor can measure the step counts during low-level walking, comparing with the pedometer using a magnetic proximity sensor. The individual error between the 5 pedometers and LC was shown in Fig.2. The distribution of individual error did not explain why the daily steps were underestimated.

Hatano [8] reported the history of pedometer. Daily physical activities, such as sitting on a seat in train, standing in bus, move by a bicycle, and stair climbing result in less than 0.5 G. The magnitude of walking at the speed of 80 m/min results in 0.6 G on average. Most pedometers count body acceleration of more than 0.5G. Therefore, under free-living conditions, a pedometer may not detect low-level physical activities.

Felton et al. [9] reported that the daily steps on Sunday were significantly different from the other days. In the present study, the subjects wore the pedometers from Monday to Friday. However, individual differences in daily steps were found. Difference in the amount of time spent on intense physical activity might have caused the differences in the daily steps among the pedometers.

Chan et al. [10] investigated the effects of an intervention using a pedometer to measure physical

activity in sedentary workers. In their study, although the intervention was for approximately 4 weeks, the daily steps were increased and then BMI, waist girth, and resting heart rate were decreased. As a result the values after the intervention were 59% of those at baseline. Therefore, an intervention using a pedometer does not always influence the daily physical activities and/or health indices.

Tudor-Lock et al. [11] reported the pedometer-based physical activity guideline. "Take 10,000 steps per day" is slogan in Japan, and a pedometer has been used for health promotion since 1960s. National Health Promotion for the 21st Century in Japan has recommended that men should take 9,200 steps/day and women should take 8,300 steps/day. The average of daily steps was 9,490 steps in younger population and 6,071 steps in elderly [3]. It has been discussed "How many steps are enough?" The present study did not examine the minimum number of daily steps, rather we estimated the accuracy of the pedometers as a tool for measuring daily physical activity.

In conclusion, a highly accurate pedometer must be used to measure daily physical activity.

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	Waist type EC-200 (Yamasa tokei Co., Japan) A magnetic proximity sensor Manual reset
	Waist type Welsupport (Nipro Co., Japan) An acceleration sensor Auto reset
	Waist type HJA-350IT (Omron Co., Japan) An acceleration sensor Auto reset
	Wrist type HK-800 (Yamasa tokei Co., Japan) A magnetic proximity sensor Manual reset
	Pocket-in type HJ-710 (Omron Co., Japan) An acceleration sensor Auto reset
	*Criterion pedometer Lifecorder Ex (Suzuken Co., Japan) An acceleration sensor Auto reset

Fig.1 Characteristics of five testing pedometers and a criterion pedometer

Table 1 The difference in total daily steps between five pedometers and a criterion pedometer

	Total daily steps	Criterion steps	
EC-200	4036.3 ± 1850.3	6350.9 ± 4596.8	NS
Welsupport	4580.6 ± 1933.4	5903.6 ± 2535.6	NS
HJA-350IT	4610.1 ± 1027.4	6534.1 ± 2084.1	P<0.05
HK-800	4862.0 ± 4522.0	4907.4 ± 2327.6	NS
HJ-710	4085.6 ± 1650.0	5271.7 ± 2125.1	P<0.01

mean±SD

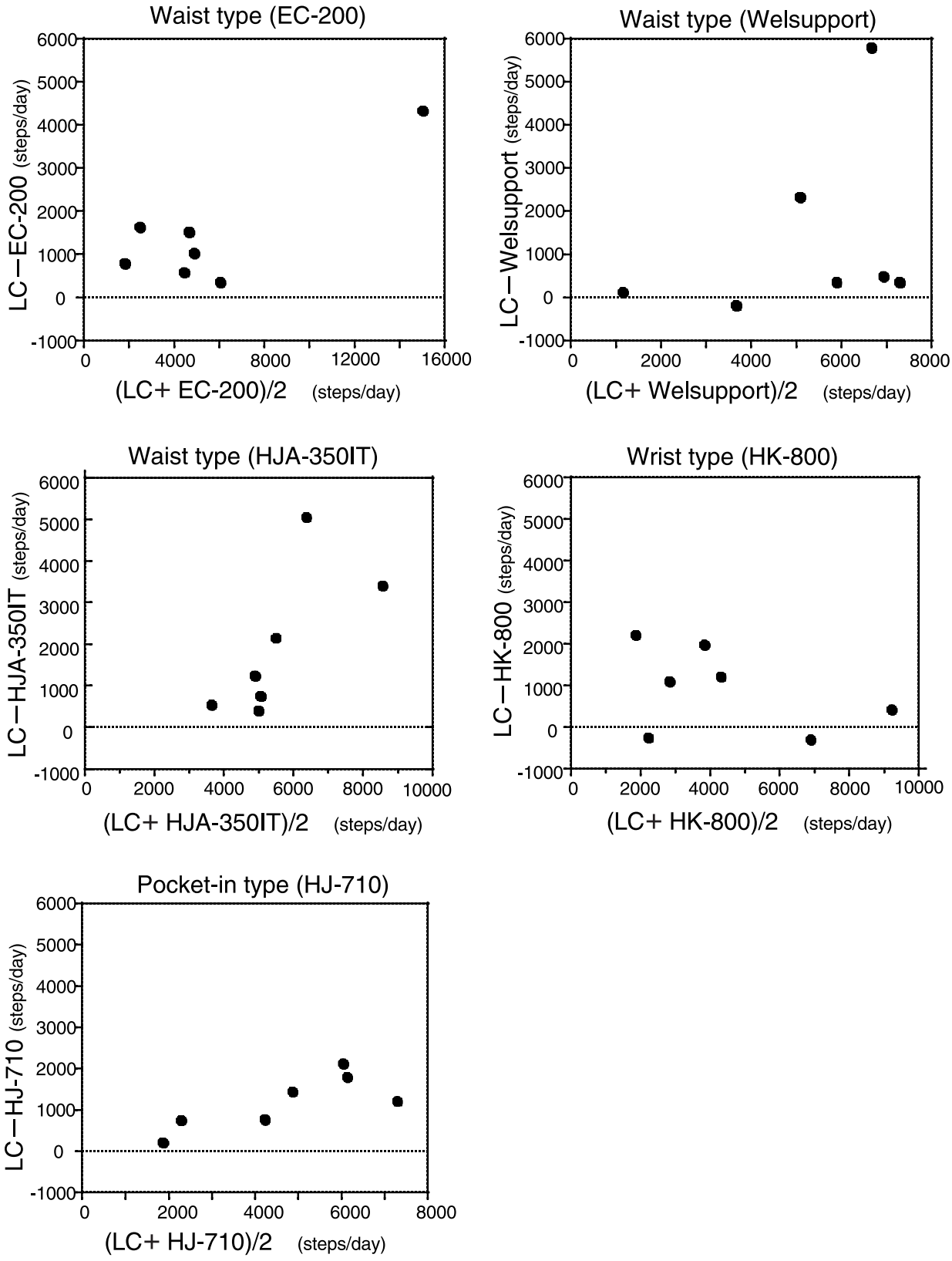

Fig.2 Bland-Altman plots showing the difference in total daily steps.

自由な生活環境下における５種類の歩数計の精度

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要旨

本研究の目的は、５種類の歩数計の精度を自由な生活環境下で検証することである。７名の被験者（年齢20.4+/-0.5才）は、２種類の歩数計を５日間装着した。一つは基準となる歩数計で、もう一つの歩数計は腰部装着型３種類(EC-200; Yamasa tokei, Welsupport; Nipro Co., HJA-350IT; Omron Co.)、腕時計型(HK-800; Yamasa tokei)、ポケットイン型(HJ-710; Omron Co.)のいずれかをランダムに、それぞれ1日間装着した。１日の歩数は6,123+/-2,027歩、1,974～10,815歩であった。基準となる歩数計と比較した際、HJA-350ITとHJ-710に有意差が認められた。ポケットイン型の歩数計はポケットの中で動くため、我々はHJ-710の精度は低いと予測していた。しかし、HJA-350ITの歩数が有意に低値を示したことは説明できない。最後に、日常身体活動の調査に歩数計を利用する際には、精度の高い歩数計を使用する必要があると思われた。

キーワード：1日の総歩数　歩数計　身体活動
2010.11.17　受理