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Positioning Commercial Pedometers to Measure Activity of Older Adults with Slow Gait: At the Wrist or at the Waist?

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Abstract. Sedentary behaviour is a major risk factor for chronic disease morbidity and mortality in aging. Measuring people activity through devices such as pedometers is a recognized intervention to motivate them for more physical activity. However, the feedback provided by these devices must be accurate in order to avoid overtraining and keep users' motivation alive. If the accuracy of pedometers has been validated for healthy people, their lack of accuracy for elderly people walking at slower pace has been reported in several studies. The emergence on the consumer's market of new devices that can be worn indifferently at the wrist or at the waist raises once more this concern. In order to evaluate whether pedometers' location influences their accuracy, we have tested three pedometers at different locations, and for several paces in a comparative study. Beyond confirming the decrease of pedometers' accuracy with speed reduction, our study reveals that pedometers should be worn at the waist rather than at the wrist. This leads us to recommend wearing pedometers at the waist when monitoring population with reduced mobility.

Keywords. Independent Living, Frail Elderly, mHealth, Walking

Introduction

There is no more need to demonstrate the importance of physical activity for older people for the prevention of disease, maintenance of independence and improvement of quality of life [1]. If physical activity is particularly important among older adults, statistics unfortunately reveal a constant decrease of activity after 65 years. A cheap and efficient intervention to motivate people activity is the use of pedometers. Indeed, the goal setting theory taught us that measuring one's activity, setting suitable goals, and receive positive feedback are motivating factors for increasing physical activities [2]. However, the efficacy of these devices to motivate people may be influenced by the quality of the feedback provided after exercising. In case this feedback is inaccurate, people may disengage from the goal pursued.

If most pedometers have demonstrated their ability to accurately count footsteps of healthy adults walking at their preferred speed, many studies have raised concerns

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about the efficacy of these devices to measure activity of older adults walking at a slower pace. Frail elderly such as diabetic, obese, or patients suffering from heart failure often walk at a slower pace (around 0.6 m/s [3], and as low as 0.4 m/s for community ambulation [4]). At such pace, many pedometers show a decrease of accuracy with relative errors going from 30% to 60% [5]–[7].

While, until recently, most pedometers were worn at the waist, the new generation of pedometers entering the market is more versatile and can also be worn at the wrist as a bracelet. The possibility to wear pedometers at different locations sets the question of the location that ensures the best accuracy. In order to respond to this question, we have conducted a comparative study to explore the impact of the location of several pedometers on their accuracy at different walking speeds.

1. Methods

A comparative study has been set up to compare three different pedometers worn at two different locations (waist and wrist) and at four walking speeds.

1.1. Instruments

Three commercial pedometers, iHealth activity monitor, Withings pulse O2, and Misfit Shine, released in 2013, have been selected for our experiment. These three devices have been selected because they can be worn either at the waist (attached to the belt) or at the wrist (as a bracelet), but also for their suitability to be used in a medical scenario. Indeed, iHealth and Withings are brands that offer a variety of medical wearables that allow monitoring a large spectrum of health parameters. Misfit has been added for its very small size, and its potential acceptance by elderly that are particularly sensitive to stigmatization.

1.2. Population

Based on a previous study demonstrating that kinematic and kinetic graph patterns did not show specific differences between elderly and young subjects, we decided to enrol healthy adults [8].

1.3. Experimental setting

The walking speed range selected for our experiment is [0.4 m/s - 0.8 m/s]. The lower limit has been chosen based on a classification of walking handicap in the stroke population proposed by Martin and al. [5] that recognizes 0.4 m/s as the minimum speed for elderly able to walk outside of their house. If 1.4 m/s is recognized as the preferred walking speed of humans, we have set our upper limit at 0.8 m/s since it is the limit determined for normal speed.

In order to control the walking speed of participants, a technique combining the regulation of the footstep frequency by a metronome and the limitation of the footstep length by a rope has been employed. Based on a study exploring the relationship between length and frequency of the footsteps of physically active women, we have chosen a ratio of 0.55 between the footstep length and the cadence [9]. Consequently, for each targeted speed, the footstep length can be determined using this ratio in the equation (1) expressing the relation between step length, speed, and cadence.

$$stepsLength = speed/cadence \quad (1)$$

$$stepsLength(cm) = \sqrt{speed * stepsLength/cadence} = \sqrt{speed(m/s) * 3300} \quad (2)$$

Furthermore, the relationship between the speed, the cadence, and the step length can be also derived from the equation (1) up to the following equation:

$$Cadence\left(\frac{steps}{min}\right) = \frac{speed\left(\frac{m}{s}\right) * 6000}{stepsLength\ (cm)} \quad (3)$$

Based on the equations (2) and (3), the different settings of the experiment are calculated and presented in Table 1.

Table 1. Relation between speed, step length, and cadence

Speed	**0.4 m/s**	**0.6 m/s**	**0.8 m/s**
Step length	36 cm	44 cm	51 cm
Cadence	66 steps/min	82 steps/min	93 steps/min

1.4. Course of the study

The experiment took place on a running track where distances were delimited using marks on the ground. For each of the pedometers selected in our study, participants wore one device attached to the belt and another as a bracelet. In a first stage, participants were requested to walk 200 m at their preferred speed. In a second phase, participants were invited to walk 100 m at a speed constrained by a rope linking their legs and a pace given by a metronome.

All walks were videotaped. The videos have been watched afterward to count the actual number of footsteps done by each participant. In order to ensure the quality of the measures, the count has been double-checked by two different persons for each walk. When the two counts were different, the process was restarted until we get two identical figures. This measure was taken as the reference value acting as baseline to be compared with the count provided by pedometers. The mean relative error was calculated by averaging, over all participants, the absolute differences between the count done by observers (actual count) and the count given by the pedometer.

2. Results

Twenty-one persons (12 women and 9 men) participated to the study. Participants' age ranged from 24 to 80 year-old with a median at 30 year-old.

The mean relative counting errors averaged over all participants at each speed and for each brand are presented in **Table 2**. Additionally, the results are presented graphically as a tornado graph (Figure 1) in order to give a more visual insight. The tornado graph provides on a single graph a vision of the influence of the speed and the position on the error rate. The left side represents the errors of pedometers worn at the wrist and the right side represents the errors of pedometers worn at the waist. Each line represents a single pedometer and each histogram branch presents the cumulated errors in percentage at each speed.

Table 2. Absolute mean relative errors in percentages

Brand	Location	Preferred speed	0.8 m/s	0.6 m/s	0.4 m/s
iHealth Activity	Wrist	10.21	14.79	26.97	62.64
	Waist	0.55	5.12	16.29	56.45
Withings Pulse O2	Wrist	14.37	30.20	64.07	88.51
	Waist	0.87	18.27	80.92	99.34
Misfit Shine	Wrist	37.16	55.08	40.18	55.90
	Waist	39.05	40.93	49.87	70.51

Regarding the brand, the results revealed that, except at 0.4 m/s, the iHealth pedometer has better accuracy than those of the other brands independently of the position. The worst model is Misfit for which the accuracy never rises above 65%.

The choice of the pedometers' location is less obvious. Indeed, if wearing an iHealth pedometer at the waist produces fewer errors than wearing it at the wrist independently of the speed, for Withings and Misfit, the wrist becomes the most appropriate position when the speed drops under 0.6 m/s.

Finally, a comparison of the accuracy regarding to the speed reveals a decrease of accuracy going along with the decrease of speed. Whereas, at natural speed, the error was inferior to 1% for iHealth and Withings pedometers when worn at the waist, the error rises quickly with speed decrease until reaching almost 100% for Withings and more than 50% for iHealth at 0.4 [m/s].

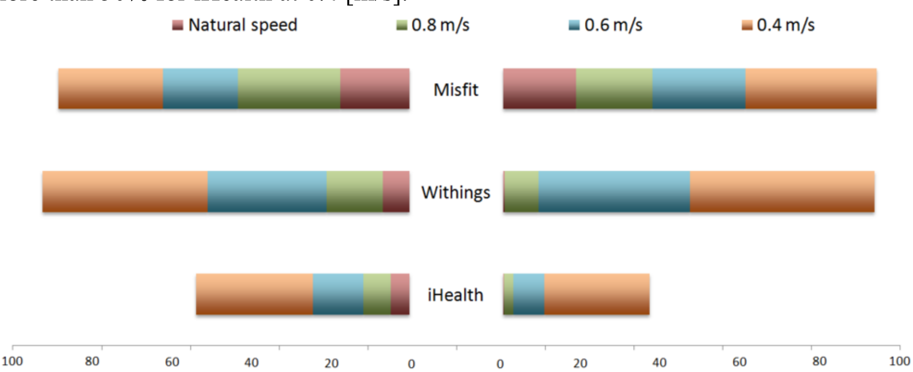

Figure 1. Tornado graph of the relative errors of pedometers for the wrist (left) and waist (right) locations

3. Discussion

The results evidence a decline of pedometers' accuracy associated to the reduction of the walking speed. This confirms the observations done in several previous studies: Schmidt-Trucksäss et al. reported errors close to 24% at 0.66 [m/s] and around 9% at 0.83 [m/s] when testing pedometers on chronic heart failure patients [3]. Martin et al., reported errors going from 9% for all devices at self-selected speed to 56% at 50 steps/min [5].

This loss of accuracy at a slow pace can be due either to the quality of the sensors inside the pedometers or to the detection algorithm. Indeed, most algorithms identify footsteps based on the vertical acceleration. Since the vertical acceleration diminishes accordingly to the speed of the walk, it is harder to detect every footstep at a slow pace. Unfortunately, as most brands keep their algorithm's specification confidential, it is not possible to draw conclusion based on these factors.

Finally, if providers advertise these new devices as versatile, with the possibility to wear them at various locations, we have observed that the accuracy clearly depends on the location they are worn. The lower accuracy of pedometers worn at the wrist is certainly due to the higher complexity of the acceleration pattern produced at this location. Indeed, at the wrist, the acceleration recorded is a combination of the vertical acceleration generated by the walk and the acceleration produced by arm movements.

4. Conclusion

Monitoring activity with pedometers has the potential to motivate people to increase physical activity. This can be particularly beneficial for frail elderly. Unfortunately, the poor performance of consumer market pedometers at low speed makes us doubt about the real effectiveness of these devices for such population.

As no validation authority controls the accuracy of consumer market pedometers, it is pretty complicated to trust these devices without performing real-world tests. Moreover, most websites that propose pedometers' comparisons rather base their reviews on aesthetic features than on the actual accuracy of devices.

If the lack of accuracy at low speed has been already demonstrated in several studies, our work emphasizes that the loss of accuracy can be further worsened if pedometers are worn at the wrist, which reduces the interest of this new generation of devices.

References

[1] F. Sun, I. J. Norman, and A. E. While, "Physical activity in older people: a systematic review.," *BMC Public Health*, vol. 13, no. 1, p. 449, 2013.

[2] C. E. Tudor-Locke, "Taking steps toward increased physical activity: Using pedometers to measure and motivate," *Pres. Counc. Phys. Fit. Sport. Res. Dig.*, vol. 3, no. 17, pp. 3–10, 2002.

[3] M. Jehn, a Schmidt-Trucksaess, T. Schuster, H. Hanssen, M. Halle, and F. Koehler, "Pedometer Accuracy in Patients with Chronic Heart Failure," *Int. J. Sports Med.*, vol. 31, no. 3, pp. 186–191, 2010.

[4] M.-V. Castell, M. Sánchez, R. Julián, R. Queipo, S. Martín, and A. Otero, "Frailty prevalence and slow walking speed in persons age 65 and older: implications for primary care.," *BMC Fam. Pract.*, vol. 14, no. 1, p. 86, 2013.

[5] J. B. Martin, K. M. Krč, E. a Mitchell, J. J. Eng, and J. W. Noble, "Pedometer accuracy in slow walking older adults.," *Int. J. Ther. Rehabil.*, vol. 19, no. 7, pp. 387–393, Jul. 2012.

[6] J. Lauritzen, A. Muñoz, J. Luis Sevillano, and A. Civit, "The usefulness of activity trackers in elderly with reduced mobility: A case study," *Stud. Health Technol. Inform.*, vol. 192, pp. 759–762, 2013.

[7] M. Marschollek, M. Goevercin, K.-H. Wolf, B. Song, M. Gietzelt, R. Haux, and E. Steinhagen-Thiessen, "A performance comparison of accelerometry-based step detection algorithms on a large, non-laboratory sample of healthy and mobility-impaired persons.," *Conf. Proc. IEEE Eng. Med. Biol. Soc.*, vol. 2008, pp. 1319–1322, 2008.

[8] W. S. Kim and E. Y. Kim, "Comparing self-selected speed walking of the elderly with self-selected slow, moderate, and fast speed walking of young adults," *Ann. Rehabil. Med.*, vol. 38, no. 1, pp. 101–108, 2014.

[9] A. Zijlstra, E. D. de Bruin, N. Bruins, and W. Zijlstra, "The step length-frequency relationship in physically active community-dwelling older women.," *Eur. J. Appl. Physiol.*, vol. 104, no. 3, pp. 427–34, Oct. 2008.