



This item was submitted to Loughborough's Institutional Repository (<https://dspace.lboro.ac.uk/>) by the author and is made available under the following Creative Commons Licence conditions.



CC creative commons
COMMONS DEED

Attribution-NonCommercial-NoDerivs 2.5

You are free:

- to copy, distribute, display, and perform the work

Under the following conditions:

BY: **Attribution.** You must attribute the work in the manner specified by the author or licensor.

Noncommercial. You may not use this work for commercial purposes.

No Derivative Works. You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

Your fair use and other rights are in no way affected by the above.

This is a human-readable summary of the [Legal Code \(the full license\)](#).

[Disclaimer](#) 

For the full text of this licence, please go to:
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

Evaluation of a commercially available pedometer used to promote physical activity as part of a national programme

Stacy A Clemes, Sophie O'Connell, Lisa M Rogan, Paula L Griffiths

Department of Human Sciences
Loughborough University
Loughborough
Leicestershire
UK, LE11 3TU

Address for correspondence:

Stacy A Clemes PhD
Department of Human Sciences
Loughborough University
Loughborough
Leicestershire
LE11 3TU
UK

Telephone: +44 (0)1509 228170
Fax: +44 (0)1509 223940
Email: S.A.Clemes@lboro.ac.uk

Keywords

Commercially available pedometers, spring-levered, piezo-electric, activity promotion, physical inactivity

ABSTRACT

Objective: To assess the accuracy of a pedometer (manufactured by Silva) currently being used as part of a national programme to promote physical activity in the UK.

Methods: Laboratory study: 68 participants (age 19.2 ± 2.7 years, BMI 22.5 ± 3.3 kg/m²) wore 2 Silva pedometers (over the right and left hips) whilst walking on a motorised treadmill at 2, 2.5, 3, 3.5 and 4mph. Pedometer step counts were compared with actual steps counted. Free-living study: 134 participants (age 36.4 ± 18.1 years, BMI 26.3 ± 5.1 kg/m²) wore one Silva pedometer, one New-Lifestyles NL-1000 pedometer and an ActiGraph GT1M accelerometer (the criterion) during waking hours for one day. Step counts registered by the Silva and NL-1000 pedometers were compared to ActiGraph step counts. Percent error of the pedometers were compared across normal-weight (n=58), overweight (n=45) and obese (n=31) participants.

Results: Laboratory study: Across the speeds tested percent error in steps ranged from 6.7 (4mph) – 46.9% (2mph). Free-living study: Overall percent errors of the Silva and NL-1000 pedometers relative to the criterion were 36.3% and 9% respectively. Significant differences in percent error of the Silva pedometer were observed across BMI groups (normal-weight 21%, overweight 40.2%, obese 59.2%, $P < 0.001$).

Conclusion: The findings suggest the Silva pedometer is unacceptably inaccurate for activity promotion purposes particularly in overweight and obese adults. Pedometers are an excellent tool for activity promotion however the use of inexpensive, untested pedometers is not recommended as they will lead to user frustration, low intervention compliance, and adverse reaction to the instrument, potentially impacting future public health campaigns

INTRODUCTION

Physical inactivity is currently a major public health concern, with latest estimates stating that approximately one third of all deaths in the UK are due to diseases which could be at least partly reduced by increased physical activity. The direct cost of physical inactivity to the NHS is estimated to be approximately £1.06 billion/year.[1] Increasing the nation's level of physical activity is therefore currently a high government priority.[2-4]

Walking has been described as an ideal form of exercise,[5] it is fundamental to most of our daily activities,[6] and is reportedly the most popular form of physical activity in the UK.[7] Indeed walking at a pace of 3 miles/hour (5km/hour) expends sufficient energy to be classified as moderate intensity activity.[8] Pedometers provide an inexpensive objective measure of ambulatory (walking) activity by counting the number of steps taken per day, and they have become a popular motivational tool for activity promotion amongst health care providers, and amongst the general public.[9] Used in interventions, pedometers have been associated with significant increases in physical activity and improvements in some key (body weight, BMI and blood pressure) health outcomes, particularly when interventions have incorporated step count recording and goal setting.[10]

Considerable variations in the accuracy of different pedometer brands have been reported,[11-17] and according to Tudor-Locke et al.[11] if we are to standardise recommendations for physical activity in terms of steps/day, it is essential that pedometers conform to a reasonable degree of accuracy. Furthermore, if commercially available pedometers are to be used to promote physical activity in large-scale programmes it is essential that they give individuals accurate daily step counts. Many resources are put into making sure that messages for such campaigns are evidence-based and it is important that the same level of attention is given to the tools used to monitor the success of participants achieving those messages.[18] The aim of the current study was to assess the accuracy of a pedometer (Silva model 56012, Silva, Sweden) currently being used as part of a UK national programme (National Step-O-Meter Programme) to promote physical activity. Despite this campaign having already been launched within the UK, there are no published validation studies for the Silva pedometer, which is used by all participants in this campaign to monitor one of the key objectives of this programme, to build towards achieving 10,000 steps/day. The Silva pedometer has a spring-suspended pendulum mechanism, it has a step count display and two reset buttons on the front and a clip on the back and costs approximately £9. Unlike most pedometers the Silva pedometer contains a filter function designed to filter out non-step movements. With the filter function, this pedometer only begins to record steps after six consecutive steps have been taken, meaning an individual taking five steps and stopping, would not have these steps counted. A secondary aim was to compare the accuracy of the Silva pedometer with that of the New Lifestyles NL-1000 pedometer (New Lifestyles, Lees Summit, MO). An earlier model of this range of pedometer (NL-2000) has been shown to be highly accurate,[13-15, 19] but the NL-1000 which uses the same piezo-electric mechanism as the NL-2000, is less expensive (\$49.95, ~£33 versus \$64.95, ~£44) and has a different design, has not previously undergone any published validation testing.

METHODS

Participants

Laboratory study: a convenience sample of 68 participants (age 19.2±2.7 years, BMI 22.5±3.3 kg/m²) recruited from the Loughborough University staff and student population completed the laboratory study.

Free-living study: a convenience sample of 134 participants (age 36.4±18.1 years, BMI 26.3±5.1 kg/m²) recruited from Leicestershire and Cornwall via word of mouth completed the free-living study.

The Loughborough University Ethical Advisory Committee approved both studies, and all participants provided written informed consent. At the outset of both studies, body mass (kg) and height (cm) were directly measured without shoes using electronic weighing scales (Tanita UK Ltd) and a wall-mounted stadiometer (Seca UK). BMI was calculated as kg/m².

Procedures

Laboratory study: participants wore two Silva pedometers (placed over the right and left hips, according to manufacturer recommendations) and a NL-1000 pedometer next to the left Silva pedometer, whilst walking on a motor-driven treadmill (Paragon CS, Horizon Fitness, UK). The study's purpose was to compare the accuracy of the pedometers relative to observed steps whilst participants walked on the treadmill at five speeds (2, 2.5, 3, 3.5 and 4 mph) for three minutes per speed. The protocol followed replicated an established treadmill protocol applied in previous pedometer validation studies.[13, 16, 17, 19-21] The treadmill was calibrated at the outset by measuring the belt length and the time required to complete 25 revolutions of the treadmill belt.

Whilst walking on the treadmill, participant's actual steps were counted by two experimenters using hand tally counters. A video camera pointing at participants' lower extremities also recorded their steps, and step counts were verified using the video recordings in the event that a different step count was reported by the two experimenters. Between each walking bout participants straddled the treadmill to enable the step counts to be recorded from each pedometer, the pedometers were then reset to zero prior to the next speed.

Free-living study: participants wore an elasticated belt containing one Silva pedometer, a NL-1000 pedometer and an ActiGraph (GT1M, Pensacola, Florida, USA) accelerometer during waking hours over a 24-hour period. The ActiGraph GT1M is a small lightweight (27g) uniaxial accelerometer, widely used in physical activity research. It is a valid and reliable tool for assessing physical activity in adults,[22, 23] and has been shown to perform well as a step counter (detecting within 1.5% of actual steps taken during treadmill walking at speeds ranging between 2 and 4 mph).[17, 20] As a result, the ActiGraph has commonly been applied as the criterion standard in studies assessing the accuracy of pedometers under free-living conditions,[11, 17, 24] during which the direct observation of actual steps taken is not feasible.

Participants were instructed to wear the belt at a position corresponding to where they usually wore their waistbands or belts of their everyday clothing. At the outset each participant was shown the correct position of the ActiGraph and the Silva and NL-1000 pedometers on the belt to ensure that the devices were placed directly above, or as close as possible, to the hip area on either side of the body. Participants either wore two motion sensors on their right hand side and one on their left, or vice versa. The positioning of the ActiGraph, Silva and NL-1000 was balanced across participants. Participants wore the belt during waking hours whilst continuing with their normal daily routine, they were instructed to only remove the belt whilst sleeping, swimming, bathing or showering. Upon removing the belt at the end of the day, participants recorded the step counts displayed by the Silva and NL-1000 pedometers in a log provided. Based upon the observation of Le Masurier and Tudor-Locke[20] that the ActiGraph erroneously detects steps during motor vehicle travel, participant's recorded odometer-recorded mileage for any motor vehicle travel that they completed during the 24 hour period to correct for ActiGraph over counting during vehicle travel, as applied in previous pedometer validation studies[11, 17]. In the same study, Le Masurier and Tudor-Locke[20] found that erroneous steps recorded during car travel by a spring-levered pedometer were not of sufficient magnitude to be a validity threat in free-living participants, no corrections to pedometer step counts were therefore made. The step counts recorded by the ActiGraph were downloaded using manufacturer recommended hardware and software (ActiLife, Pensacola, Florida, USA).

Statistical analyses

Statistical analyses for the laboratory and free-living studies were conducted using SPSS for Windows version 16. In both studies statistical significance was set at $P < 0.05$.

Laboratory study: Repeated-measures ANOVAs, with Bonferroni corrected post hoc comparisons, were applied to test for differences between actual counted steps and those recorded by the pedometers at each speed of treadmill walking. The differences between actual steps taken and steps detected by each pedometer (steps detected – actual counted steps) were calculated for each walking speed. Percent error of the Silva and NL-1000 pedometers at each walking speed, relative to actual steps taken were calculated ($((\text{Steps detected} - \text{actual counted steps}) / \text{actual counted steps}) * 100$) and expressed as absolute percent error.[17] Direction of percent error was categorized as under- ($<1\%$), exact (within $\pm 1\%$), or over- ($>1\%$) counting of actual steps and presented as frequencies. This strict criterion has been applied in previous studies[11, 17] and is based upon earlier observations by Bassett et al.[16] that the spring-levered Yamax pedometer was accurate to within 1% of actual steps taken during treadmill walking at 3mph.

Free-living study: ActiGraph step counts were corrected for vehicle travel by subtracting 12.5 steps per mile travelled.[20] Percent error of the Silva and NL-1000 pedometers relative to the ActiGraph were calculated ($((\text{pedometer steps} - \text{corrected ActiGraph steps}) / \text{corrected ActiGraph steps}) * 100$) and expressed as absolute percent error. Direction of percent error was categorised as under- ($<10\%$), acceptable (within $\pm 10\%$), or over- ($>10\%$) counting in relation to corrected ActiGraph steps/day. This 10% standard was based upon the recommendation of Tudor-Locke et al.[11] that under free-living conditions, pedometers should detect within 12-22% of the ActiGraph, or be within 10% of ActiGraph steps at least 60% of the time. Bland-Altman plots were constructed to show the distribution of the individual pedometer error scores around zero (pedometer steps – corrected ActiGraph steps).[25] Using these plots, for each pedometer the mean error can be illustrated along with the 95% prediction interval (95% confidence interval for the individual observations). Accurate devices show a tight prediction interval around zero. To investigate whether the accuracy of the pedometers varied by BMI, absolute percent errors of each pedometer were compared across normal-weight ($\text{BMI} < 25 \text{ kg/m}^2$) overweight ($\text{BMI} = 25\text{--}29.9 \text{ kg/m}^2$) and obese ($\text{BMI} \geq 30 \text{ kg/m}^2$) participants using a one-way ANOVA, with Bonferroni-corrected post hoc comparisons.

RESULTS

Laboratory study: Steps detected by the right and left Silva pedometers were significantly lower than actual steps counted at all speeds (all $P < 0.008$). Steps detected by the right and left Silva pedometers were significantly different from each other at 2.0 and 2.5 mph ($P < 0.001$), no differences between the two Silva pedometers were observed at the remaining speeds (Figure 1). Steps recorded by the NL-1000 did not differ significantly from actual steps taken at all speeds, except at 2 mph ($P < 0.01$).

Figure 1

Absolute percent errors of each pedometer, relative to actual steps taken, at each walking speed are shown in Table 1. According to Tudor-Locke et al.[11] steps recorded by pedometers should be within 1% of actual steps taken at 3 mph. On average, the two Silva pedometers undercounted at 3 mph ($<1\%$ of actual steps) 66.9% of the time, they were within 1% of steps taken 24.3% of the time, and they over counted ($>1\%$ of actual steps taken) 8.8% of the time. Corresponding values for the NL-1000 were: undercounted 14.7% of the time, within 1% of steps taken 70.6% of the time, and over counted 14.7% of the time.

Table 1. Actual steps taken, and absolute percent error of each pedometer at each walking speed (mean [SD]).

| Speed (mph) | Actual steps taken | Absolute percent error of each pedometer | | |
|-------------|--------------------|--|-------------|-------------|
| | | Left Silva | Right Silva | NL-1000 |
| 2.0 | 278.3 (53.4) | 46.9 (37.9) | 30.5 (38.7) | 12.9 (15.8) |
| 2.5 | 310.7 (59.6) | 23.9 (31.9) | 16.7 (28.0) | 3.0 (6.4) |
| 3.0 | 335.0 (62.0) | 12.0 (22.0) | 8.9 (20.4) | 0.5 (1.0) |
| 3.5 | 359.6 (65.9) | 7.0 (17.8) | 8.0 (18.8) | 0.8 (2.3) |
| 4.0 | 383.3 (71.7) | 6.7 (15.0) | 9.3 (19.8) | 0.9 (2.0) |

Free-living study: On average participants wore the motion sensors for 11.9 (SD = 2.5) hours under free-living conditions. Mean step counts detected by each motion sensor are shown in Table 2. Absolute percent error of the Silva and NL-1000 pedometers, relative to corrected ActiGraph steps were 36.3% and 9.0% respectively. Steps detected by the Silva pedometer were within 10% of corrected ActiGraph steps 19.4% of the time. The Silva pedometer undercounted (<10%) 76.1% of the time and over counted (>10%) 4.5% of the time. In comparison, steps detected by the NL-1000 were within 10% of corrected ActiGraph steps 69.2% of the time, the NL-1000 undercounted (<10%) 3.0% of the time and over counted (>10%) 27.8% of the time.

Table 2. Mean (SD) daily step counts detected by each motion sensor, along with absolute percent error of the two pedometers relative to corrected ActiGraph steps for the sample as a whole, and for each BMI sub-group. ActiGraph step counts are corrected for motor vehicle transport.

| | ActiGraph corrected steps/day | Silva | | NL-1000 | |
|------------------------|-------------------------------|-------------|------------------------|-------------|------------------------|
| | | Steps/day | Absolute percent error | Steps/day | Absolute percent error |
| Whole sample (n = 134) | 6969 (3408) | 4944 (3726) | 36.3 (29.4) | 7448 (3649) | 9.0 (5.9) |
| Normal weight (n = 58) | 8057 (3909) | 6557 (3800) | 21.0 (18.7) | 8621 (4107) | 8.6 (5.2) |
| Overweight (n = 45) | 6601 (3016) | 4504 (3379) | 40.2 (29.0) | 7119 (3275) | 9.7 (7.3) |
| Obese (n = 31) | 5469 (2076) | 2567 (2495) | 59.2 (30.3) | 5771 (2386) | 8.7 (5.1) |

Figure 2 shows the Bland-Altman plots for the Silva and NL-1000 pedometers. To aid interpretation of the findings, the y-axes have been standardised to highlight the differences in accuracy between the two pedometers. On average the Silva pedometer under counted by 2025 ± 1903 steps/day (95% prediction interval ± 3806 steps/day), whilst the NL-1000 over counted by an average of 479 ± 506 steps/day (95% prediction interval ± 1012 steps/day).

Figure 2.

Mean daily step counts detected by each motion sensor, along with absolute percent error of the Silva and NL-1000 pedometers relative to corrected ActiGraph steps, for each BMI group are shown in Table 2. There was a significant overall effect of BMI on absolute percent error of the Silva pedometer ($F = 23.6$, $P < 0.001$), with post hoc analyses revealing that absolute error of the Silva pedometer varied significantly between all three BMI groups (Table 2). In

comparison, there were no significant effects of BMI on absolute error of the NL-1000 ($F = 0.5$, $P = 0.58$).

DISCUSSION

The aim of this study was to assess the accuracy of the Silva pedometer currently being used as part of a UK national programme (National Step-O-Meter Programme, run in conjunction with the NHS) to promote physical activity. Findings from the laboratory and free-living studies showed that the Silva pedometer under counted steps on the majority of occasions, and the large absolute percent errors recorded in the two studies indicate that the Silva pedometer is unacceptably inaccurate for activity promotion purposes. These findings are similar to those of previous studies assessing the accuracy of inexpensive pedometers used to promote physical activity through mass distribution to the general population.[11, 12] The observation from the free-living study that the Silva pedometer's accuracy declines even further with increasing BMI is particularly concerning given that overweight and obese adults are likely to be targeted by their health care provider for programme participation. In contrast, the findings show that the NL-1000 is a highly accurate research-grade pedometer, suitable for use across all BMI groups.

The accuracy of other pedometers using a similar spring-levered mechanism to the Silva pedometer have also been shown to decline with increasing BMI under controlled conditions, whilst no effects of BMI on the accuracy of a piezo-electric pedometer were found in the same study.[19] The findings from the free-living study extend this observation as the accuracy of the piezo-electric NL-1000 did not vary with BMI group. Crouter et al.[19] observed that the accuracy of a spring-levered pedometer was influenced by tilt angle in overweight and obese participants. Whilst pedometer tilt was not measured in the current study, pedometer tilt may explain the further reductions in accuracy of the Silva pedometer seen in our overweight and obese participants as the manufacturer have stated that accuracy of this pedometer declines at tilt angles exceeding plus/minus 15 degrees.[18] Based on the current findings, and those of Crouter et al.[19] the evidence shows that a piezo-electric pedometer would be better suited for health promotion strategies targeting overweight and obese adults.

In the laboratory study absolute percent error of the Silva pedometers were greatest at the slower walking speeds (2 and 2.5 mph). Other pedometers with a similar spring-levered mechanism have consistently been shown to be less accurate at speeds under 3 mph,[13, 16, 17, 19-21, 26] which raises concerns about the use of these types of pedometer (pendulum/spring-levered) in obese and elderly individuals who have a tendency to ambulate at slower speeds (<2.5 mph).[26] Melanson et al.[26] and Crouter et al.[19] have both shown that piezo-electric pedometers are more sensitive at slower speeds and may therefore be a better choice of pedometer for individuals with a slower walking pace. The findings from the current laboratory study support these suggestions as absolute percent error of the NL-1000 at 2.5 mph was 3.0% compared to 16.7% and 23.9% for the right and left Silva pedometers.

The 10,000 steps/day goal has gained popularity in the UK and US over the past few years and indeed participants in the National Step-O-Meter programme are encouraged to achieve this goal.[18] However, if any step count goal is to be meaningful it is essential that some degree of standardisation is present between pedometer brands that help individuals to assess whether they are achieving their goal.[15] It is likely that the Silva pedometer's filter function is partly responsible for the large discrepancy seen between the step counts derived from this pedometer and the ActiGraph criterion in our free-living study. However, based upon the findings from our laboratory study, which involved bouts of continuous walking on a treadmill, the filter function is not solely responsible for this pedometer's tendency to undercount daily steps. Under laboratory conditions the absolute percent error of the Silva pedometer across the speeds tested ranged from 6.7 to 46.9%. A further possible

explanation for the Silva pedometers tendency to under count may be accidental resetting of the pedometer caused by participants inadvertently pressing the unprotected reset buttons on the front of the pedometer, although this would not be a source of the error during the laboratory study as participants were observed not to touch the pedometers during this testing. In contrast, the NL-1000 has a cover to protect against accidental resetting. The inaccuracy of the Silva pedometer during treadmill walking, coupled with the pedometer's filter function and possible accidental resets, resulted in vast underestimates of steps taken relative to the ActiGraph and NL-1000 under free-living conditions.

Given the 10,000 steps/day target was devised using pedometers without a filter function, and based upon early recommendations in Japan whereby pedometers have to meet the Japanese Industrial Standard, set by the Ministry of Industry and Trading regulations which requires less than a 3% margin of error,[27] it is suggested that the 10,000 steps/day goal maybe unrealistic for most adults using the Silva pedometer. For example, given the 36% difference between steps derived from the Silva pedometer and those counted by the ActiGraph, it is possible that to achieve a daily step count of 10,000 steps/day according to the Silva pedometer, an individual would actually need to be taking 13,600 steps/day, this number would be even higher in obese adults (15,900 steps/day) where a greater discrepancy (~59%) between Silva steps and ActiGraph steps were observed. It is possible that due to this pedometers tendency to undercount some individuals may have to actually take twice as many steps to achieve their targets which is likely to cause frustration and desperation for both the individual and their general practitioner[26] and may actually be a health risk to a morbidly obese patient because their fitness levels may not be appropriate to undertaking this level of physical activity. The individuals most likely to be affected are the most obese, who will be most in need of positive feedback and benefits from intervention.

Given today's strong focus on evidence-based medicine for pharmaceutical treatments, it is important that the same level of evidence-based medicine is applied to the tools used to motivate individuals in public health interventions. Whilst the evidence exists for the positive effects of walking interventions on health outcomes,[28] and the role of pedometers in motivating individuals to achieve targets,[10] the current findings highlight that the Silva pedometer used in the National Step-O-Meter Programme is not appropriate to use to monitor walking given its high level of inaccuracy.

A strength of the current study is that we have performed a comprehensive, independent, evaluation of the Silva pedometer's accuracy under controlled and free-living conditions using established protocols. In the free-living condition the relatively large, and diverse, sample recruited enabled the Silva pedometer's accuracy to be compared across different BMI groups. A limitation however of the laboratory condition was the relatively small numbers of overweight and obese adults, which precluded meaningful comparisons between the accuracy of the Silva pedometer across BMI groups.

In conclusion, the findings suggest the Silva pedometer is unacceptably inaccurate for activity promotion purposes particularly in overweight and obese adults. Given that the Silva pedometer is already being used in the UK's National Step-O-Meter programme, this paper's findings highlight the importance of focusing as much attention on the evidence base for monitoring tools for public health campaigns as is currently given to building appropriate messages for such campaigns. Pedometers are an excellent tool for promoting physical activity however the use of inaccurate devices is counter productive since this will result in frustration, low compliance to an intervention, and adverse reaction to the instrument which could negatively affect future public health campaigns.[11, 12] In the UK similar industrial standards to those applied in Japan should be enforced to all commercially available pedometers to ensure that the British public have the opportunity to use, and benefit from, an accurate pedometer to monitor walking activity.

WHAT THIS PAPER ADDS

What is already known on this subject

Pedometers are a popular motivational tool for activity promotion amongst health care providers, and amongst the general public.

Used as an intervention tool, pedometers have been associated with significant increases in physical activity and improvements in some key (body weight, BMI and blood pressure) health outcomes.

What this study adds

The Silva pedometer, currently being used as part of the National Step-O-Meter Programme, is unacceptably inaccurate for activity promotion purposes.

Inaccuracy of the Silva pedometer increases further with increasing BMI.

The use of inexpensive, untested pedometers is not recommended as they will lead to user frustration, low intervention compliance, and adverse reaction to the instrument, potentially impacting future public health campaigns.

Competing interests

The authors declare that there are no competing interests associated with the research contained within this manuscript.

Funding

No financial support was received from any pedometer companies, importers, or retailers. No external funding supported the work outlined in the article; the study was conducted using resources from the Department of Human Sciences and Faculty of Science at Loughborough University.

Exclusive License

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non-exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd and its Licensees to permit this article (if accepted) to be published in British Journal of Sports Medicine and any other BMJPG products to exploit all subsidiary rights, as set out in our licence (<http://bjsm.bmj.com/ifora/licence.pdf>).

FIGURE LEGENDS

Figure 1. Mean differences in steps detected by the three pedometers and actual steps taken, along with standard error bars.

Figure 2. Bland-Altman plots for the Silva and NL-1000 pedometers. The solid line represents the mean error score (steps detected by pedometer – corrected ActiGraph steps) for each pedometer, and the dashed lines represent the 95% prediction intervals (95% confidence intervals of the individual observations).

REFERENCES

- 1 Allender S, Foster C, Scarborough P, *et al.* The burden of physical activity-related ill health in the UK. *J Epidemiol Community Health* 2007;**61**:344-8.
- 2 Department of Health. Choosing activity: a physical activity action plan. Crown Copyright 2005.
- 3 Department of Health. Healthy weight, healthy lives: A cross-Government strategy for England. Crown Copyright 2008.
- 4 Department of Health. Be active, be healthy: a plan for getting the nation moving. Crown Copyright 2009.
- 5 Morris JN, Hardman AE. Walking to health. *Sports Med* 1997;**23**:306-32.
- 6 Tudor-Locke CE, Myers AM. Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Med* 2001;**31**:91-100.
- 7 Chief Medical Officer. At least five a week: evidence on the impact of physical activity and its relationship to health. Crown Copyright 2004.
- 8 Ainsworth BE, Haskell WL, Whitt MC, *et al.* Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;**32**:S498-504.
- 9 Clemes SA, Griffiths PL, Hamilton SL. Four-week pedometer-determined activity patterns in normal weight and overweight UK adults. *Int J Obes (Lond)* 2007;**31**:261-6.
- 10 Bravata DM, Smith-Spangler C, Sundaram V, *et al.* Using pedometers to increase physical activity and improve health: a systematic review. *JAMA* 2007;**298**:2296-304.
- 11 Tudor-Locke C, Sisson SB, Lee SM, *et al.* Evaluation of quality of commercial pedometers. *Can J Public Health* 2006;**97 Suppl 1**:S10-5, S-6.
- 12 De Cocker K, Cardon G, De Bourdeaudhuij I. Validity of the inexpensive Stepping Meter in counting steps in free living conditions: a pilot study. *Br J Sports Med* 2006;**40**:714-6.
- 13 Crouter SE, Schneider PL, Karabulut M, *et al.* Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc* 2003;**35**:1455-60.
- 14 Schneider PL, Crouter SE, Lukajic O, *et al.* Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. *Med Sci Sports Exerc* 2003;**35**:1779-84.
- 15 Schneider PL, Crouter SE, Bassett DR. Pedometer measures of free-living physical activity: comparison of 13 models. *Med Sci Sports Exerc* 2004;**36**:331-5.
- 16 Bassett DR, Jr., Ainsworth BE, Leggett SR, *et al.* Accuracy of five electronic pedometers for measuring distance walked. *Med Sci Sports Exerc* 1996;**28**:1071-7.
- 17 Le Masurier GC, Lee SM, Tudor-Locke C. Motion sensor accuracy under controlled and free-living conditions. *Med Sci Sports Exerc* 2004;**36**:905-10.
- 18 National Step-O-Meter Programme. Evidence guide and user's handbook: Walking the Way to Health Initiative; 2006.
- 19 Crouter SE, Schneider PL, Bassett DR, Jr. Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports Exerc* 2005;**37**:1673-9.
- 20 Le Masurier GC, Tudor-Locke C. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc* 2003;**35**:867-71.
- 21 Swartz AM, Bassett DR, Jr., Moore JB, *et al.* Effects of body mass index on the accuracy of an electronic pedometer. *Int J Sports Med* 2003;**24**:588-92.
- 22 Melanson EL, Jr., Freedson PS. Validity of the Computer Science and Applications, Inc. (CSA) activity monitor. *Med Sci Sports Exerc* 1995;**27**:934-40.
- 23 Welk GJ, Schaben JA, Morrow JR, Jr. Reliability of accelerometry-based activity monitors: a generalizability study. *Med Sci Sports Exerc* 2004;**36**:1637-45.
- 24 Tudor-Locke C, Ainsworth BE, Thompson RW, *et al.* Comparison of pedometer and accelerometer measures of free-living physical activity. *Med Sci Sports Exerc* 2002;**34**:2045-51.
- 25 Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;**1**(8476):307-10.
- 26 Melanson EL, Knoll JR, Bell ML, *et al.* Commercially available pedometers: considerations for accurate step counting. *Prev Med* 2004;**39**:361-8.

- 27 Hatano Y. Use of the pedometer for promoting daily walking exercise. *International Council for Health, Physical Education, and Recreation* 1993;**29**:4-8.
- 28 Ogilvie D, Foster CE, Rothnie H, *et al.* Interventions to promote walking: systematic review. *BMJ* 2007;**334**:1204.

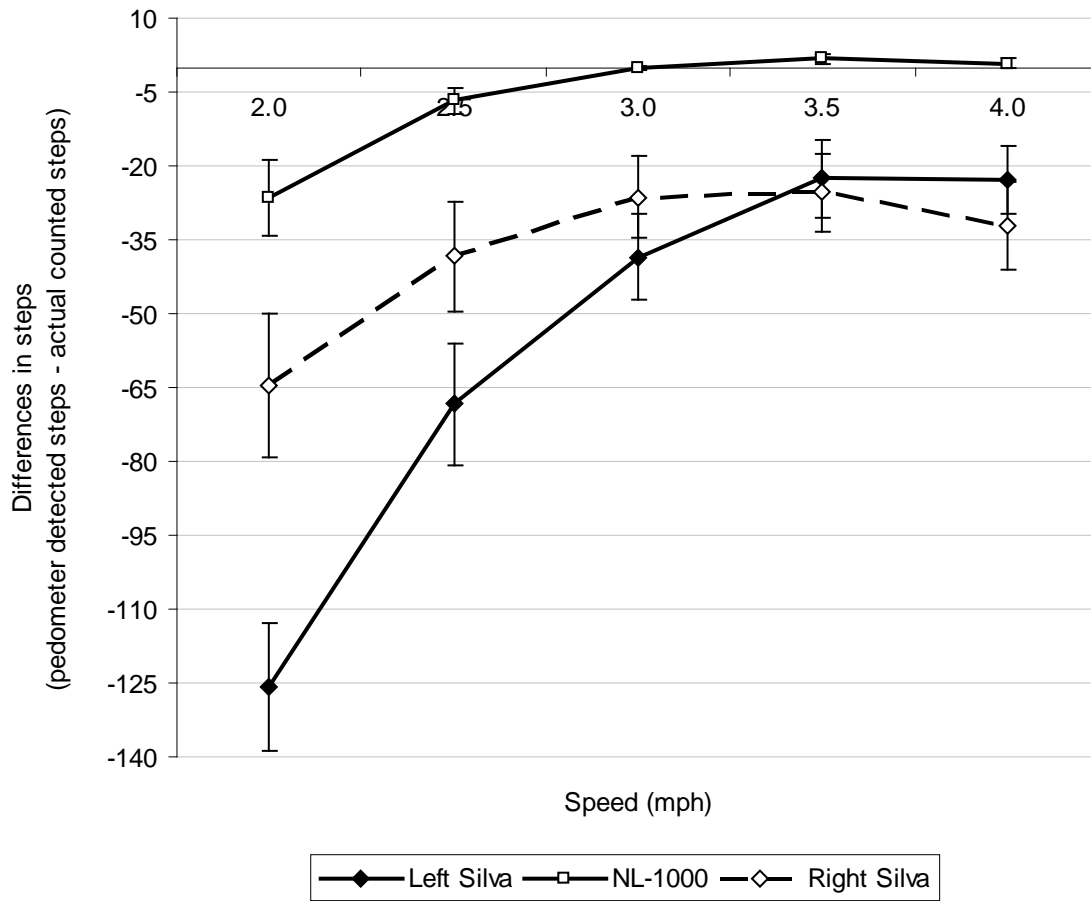


Figure 1

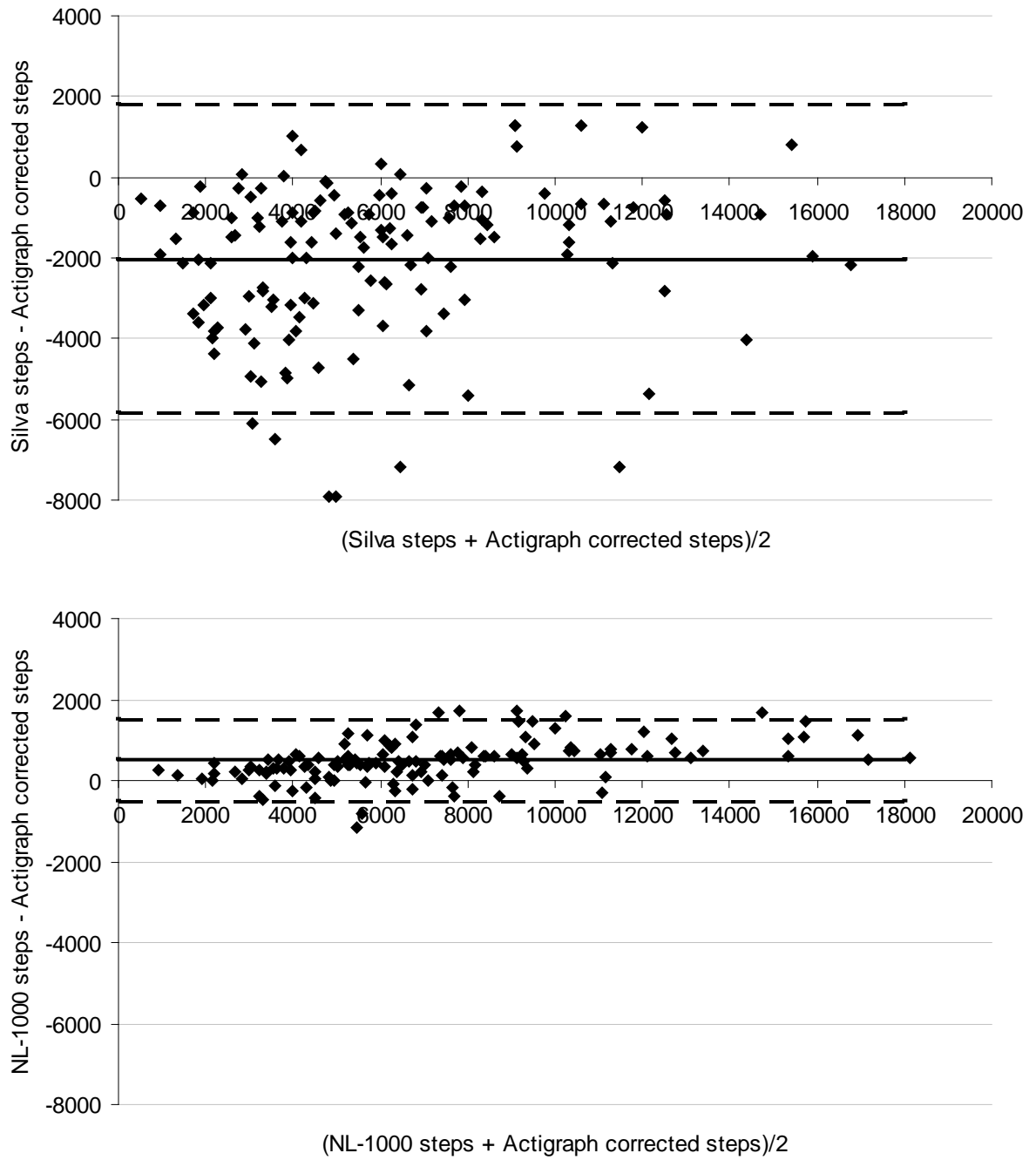


Figure 2