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Research Article

Comparison of Electronic and Self-Reported Pedometer Step Counts in a Dog Walking Study

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Abstract

Some pedometers capture an electronic record of steps, while others require that participants read step counts from the pedometer and record them in a separate log. This study characterizes discrepancies between self-report and electronic capture of daily step counts, compares compliance between methods over time, and assesses reliability and validity of average daily step counts using both methods. Daily step counts were obtained from a sample of 29 participants over a three-month period using both electronically stored pedometer recordings and paper-and-pencil activity logs based on pedometer readings. Differences in compliance and average step counts between pedometer and self-reported were low to moderate, and self-reported step counts were of sufficient quantity and quality that they provide a reliable, valid and possibly less expensive alternative to pedometer step counts.

The purpose of this paper is to identify and characterize discrepancies between self-report and electronic capture of daily step counts in a sample of participants asked to wear a pedometer for three months. We also compare compliance between methods over time, and assess reliability and validity of average daily step counts using both methods. We hypothesize that electronic capture of daily step counts will be associated with higher compliance, and more valid and reliable data than self-report of daily step counts in a hand-written activity log

Keywords: Compliance; Dog walking; Physical activity; Reliability; Self-report; Validity

Introduction and Background

Using Pedometers for Activity Measurement

Pedometers provide a convenient and inexpensive way for researchers to measure physical activity by counting steps taken by study participants [1]. Participants in activity studies lasting one week or longer have traditionally been asked to read daily step counts from the pedometer and record them in a pencil-and-paper diary or logbook, or more recently, an electronic diary [2]. Some current pedometer models include an internal data storage mechanism that records daily step counts to be downloaded to a computer for analysis. These pedometers tend to be more expensive than those without data storage. However, they may yield more accurate results than self-report data. Fewer days of data may be reported in a logbook or diary than are downloaded from a pedometer because of participant non-compliance with self-reporting. The quality of self-reported data may be lower if participants over-report steps due to social desirability bias [3] if they back-fill or forward-fill missed days [4] or if they transcribe step counts incorrectly from the pedometer. A review of direct versus self-report measures of physical activity [5] found that in 7 of 8 studies involving pedometers, self-reported exceeded pedometer-measured physical activity. However, these studies did not compare two different methods of pedometer reporting.

Fukuoka et al. [2] showed good agreement between self-reported daily steps by mobile phone diary and pedometer-recorded daily steps in a three-week pilot, but their study collected only 3 weeks of step data and did not include a pencil and paper component. Behrens et al. [6] found small differences between self-reported and pedometer-recorded steps of about 100 steps per day, but this study was conducted over only nine days so does not address changes in agreement and/or compliance over time. Reflecting an expanding market of devices used to measure steps, more and more studies compare the use of different types of pedometers or activity monitors [7, 8,9,10,11,12,13]

Specific to human animal interaction studies, pedometers have been used to measure walking behavior [14,15,16,17,18] For example, Rhodes and his colleagues [19] instructed inactive dog owners in both control and intervention groups in their study to wear a pedometer called the Lifestyles Digi-Walker SW for one week from morning to night and to record their daily step counts in a pedometer log. The study revealed that physical activity increased significantly for those participants in the intervention group. Commitment to their animal companions and responsibility for the promotion of their dogs' health was seen as contributing to more frequent walking behavior or other opportunities to exercise with one's pet [20,21]. This commitment was underscored as a motivational factor in the qualitative study conducted by Higgins and her colleagues [22]. Other studies used pedometers with dogs being seen in a veterinary obesity clinic to examine and compare physical activity in normal, overweight and obese dogs [23]. These researchers indicated that "pedometers are highly adaptable as reflected by their use in studies of various species of animals including dogs, cattle, horses, and turkeys" [23].

Thus, the use of pedometers in studies designed to measure physical activity cuts across fields of study, and pedometers have been increasingly used in research on dog walking. We report what was learned about pedometer use in our study of owners and pets exercising together so that others might benefit as they design similar studies.

Research Question

The purpose of this paper is to identify and characterize discrepancies between self-report and electronic capture of daily step counts in a sample of participants asked to wear a pedometer for three months. We also compare compliance between methods over time, and assess reliability and validity of average daily step counts using both methods. We hypothesize that electronic capture of daily step counts will be associated with higher compliance, and more valid and reliable data than self-report of daily step counts in a hand-written activity log.

Methods

Participants

Adult owners of overweight dogs [24] were recruited as part of a parent study to assess the effects of veterinary counseling on owner and pet activity and weight-related health outcomes. Exclusion criteria included planned medical procedures for the dog or owner, anticipated inability to engage in physical activity for longer than 7 days, and diagnosed medical conditions that would exclude dog owners from participating in regular physical activity. Additional details about the original study are published elsewhere [25,26,27,28] The study was approved by the Institutional Review Board (IRB) and the Institutional Animal Care and Use Committee (IACUC) of the Uniformed Services University of the Health Sciences.

Procedures

Lifecorder EX™ pedometers were provided to all participating dog owners one week prior to a planned intervention involving physical activity counseling. The validity of the Life order™ pedometer has been previously established using indirect calorimetry [29]. Dog owners were randomized to one of two study groups. One group was counseled to spend at least 30 minutes per day engaged in physical activity with their dog. The other group received standard counseling regarding activity for the dog, but no counseling regarding targeted dog owner behavioral changes. The baseline visit included a demonstration by study staff on how to properly wear the pedometer. After this initial randomization, dog owners in both groups were asked to wear a pedometer daily for three months to monitor their activity level. They were given an activity log and asked to transcribe daily step counts from the pedometer into the activity log at the end of each day. They also recorded time spent wearing the pedometer and time spent engaged with their dog in physical activity every day.

At the three-month follow-up visit, study staff collected the activity logs and pedometers, downloaded data from the pedometers and manually entered data from the activity log into the database. No significant differences in step counts were observed between the two study groups, which are pooled for this analysis.

Measures

Self-reported daily step counts ("activity log step counts") were obtained from participant paper logbooks, and electronically-recorded step counts ("pedometer step counts") were downloaded from participant pedometers at the end of the study. Step counts exclude a one-week baseline study run-in period during which pedometers were set so that participants could not see the step counts. There were no comparable activity log step counts for that week. Daily self-reported start and stop times for pedometer use were analyzed to determine how many hours the pedometer was worn each day.

Statistical Analysis

Step counts were summarized using basic descriptive statistics. Daily step counts were averaged over the entire study period for each subject to represent typical activity. Daily step counts of less than 1,000 steps were treated as missing data for calculation of typical activity because they tended to represent days on which the pedometer was not worn or worn only briefly. Step counts, and days of use were compared between activity log and pedometer using paired t tests, and proportion meeting compliance targets was compared using McNemar's chi square test for paired proportions. The Bland-Altman method [30] was used to summarize discrepancies between activity log and pedometer step counts.

The intraclass correlation (ICC) was used to establish reliability of average daily step counts over time. Subsets of the data were created starting on days 1, 6, 11, 16, 21, 26, 31 and 36, and extending for 7 days so that eight different ICC estimates were obtained for 7 days of monitoring. Observed ICC coefficients were averaged across the eight subsets to obtain the average ICC for a 7-day observation period. This process was repeated for 14, 21, 28 and 35-day observation periods. The ICC was based on a two-way mixed model, and pertains to the entire observation period rather than an individual day [31]. Data were analyzed using SAS® version 9.3 (SAS Institute, Cary, NC).

Results

Sample Characteristics

A total of 41 participant dog owners were randomized to intervention or control; of these, 35 wore pedometers and provided at least partial step count data. Two pedometers (6%) failed and steps could not be downloaded at the end of the study. Four dog owners (11%) wore the pedometer but did not record step counts in the daily log. Twenty-nine dog owners provided both activity log and pedometer step counts and data analysis is based on these participants. Dog owners were predominantly female (90%) with an average age of 43 years (range, 18-73 years). Most were married (58%) white (86%) non-Hispanic (86%) college graduates (66%) with annual income exceeding $80,000 (55%) and living with others (83%).

Compliance

Overall compliance with pedometer-wearing instructions was mixed (Table 1). Only eight of 29 pedometers registered at least 90 days of positive step counts, and only four dog owners recorded step counts in the activity log on at least 90 days. Dog owners averaged 82 days with positive pedometer step counts (91% compliance). Dog owners recorded steps in the activity log on an average of 72 days (80% compliance; P < .001 vs. pedometer). Self-reported average hours per day of pedometer use ranged from 10.1 to 16.4 with a mean of 13.5.

	Pedometer	Self-report (activity log)	P value*
Average days with step count > 0	82 (32-186)	72 (14-170)	<.001
Average days with step count > 1,000	76 (31 – 186)	72 (12 – 170)	<.001
N (%) of subjects with 90 days with step count > 0	8 (28%)	4 (14%)	.045
90 days with step count > 1,000	7 (24%)	4 (14%)	.083
Average hours worn		13.5 (10.1-16.4)	
Data are mean (range) unless otherwise noted. *Paired t test (means) or McNemar's chi square (proportions)			

Table 1: Pedometer use and compliance with self-report over 90 days of monitoring (n=29).

Compliance increased from week one to week two and peaked in the first month of the study. Compliance stayed above 70% (for pedometer) and above 60% (for activity log) through week 12, dropping off in the final week of the study (Figure 1). Pedometer compliance remained consistently higher than activity log compliance throughout the study.

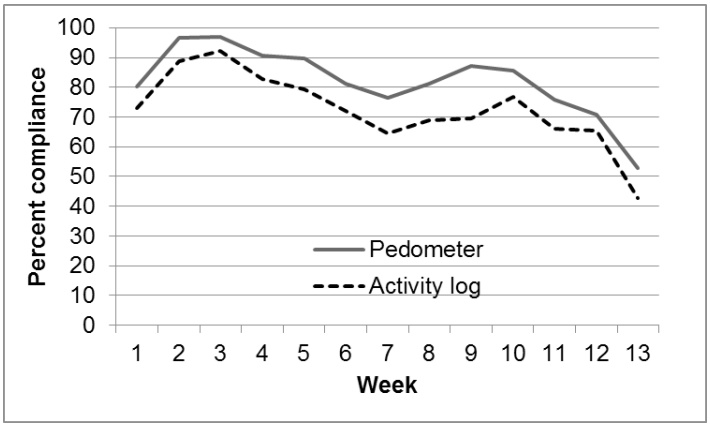

Figure 1: Changes in compliance over time.

There were 424 person-days on which fewer than 1,000 steps were recorded on the pedometer. This tended to occur on days when no activity log entry was made (n=380 days), suggesting that the pedometer was not worn, or when the activity log entry indicated that the pedometer was worn for fewer than six hours (n=9 days). When only days with at least 1,000 steps are counted as compliant, the difference in compliance between pedometer and activity log narrows to only four days (4.4%), although it is still statistically significant (72 days for logbook, 76 days for pedometer, P < .001).

Discrepancies in Daily Step Counts

Self-reported daily steps ranged from 383 to 29,907 with a mean of 8,719 steps per day (standard deviation 4,537), while pedometer daily steps ranged from 3 to 29,914 with a mean of 8,675 steps (standard deviation 4,594). Although step counts below 1,000 were excluded from calculations of typical activity, they were included in the analysis of daily step counts in order to fully characterize discrepancies. Differences between log and pedometer step counts were common; the two records matched exactly for only 259 of 2,077 person-days (12.5%). However, 78%

of person-days (1,617) reflect a difference of less than 1% of the average daily step count (87 steps).

Agreement between average step counts from pedometer and activity log Daily step counts for each dog owner were averaged over the entire observation period to obtain participant average step counts, excluding days on which fewer than 1,000 steps were recorded. Despite the observed differences between pedometer and activity log step counts on specific days, average step counts for the two methods were quite similar, with pedometer step counts averaging 8,736 (standard deviation 3,272 steps) and activity log step counts averaging 8,859 (standard deviation 3,263 steps). The average difference between the methods was only 123 steps (95% CI, 5 to 240 steps, P = .041), or less than 2% of average daily steps. The Bland-Altman limits of agreement (Figure 2) are -493 to 738 steps, indicating that differences of more than about 9% between activity log and pedometer average step counts are expected less than 5% of the time. Intraclass correlation between the two methods was high at 0.99.

Agreement remained fairly constant over time. There was a tendency for pedometer steps to exceed self-reported steps in the first week of the study, while in subsequent weeks self-reported steps tended to exceed pedometer steps. Average differences, however, remained small relative to total daily steps – for each week, the difference was fewer than 400 steps, or 5% of daily steps (data not shown).

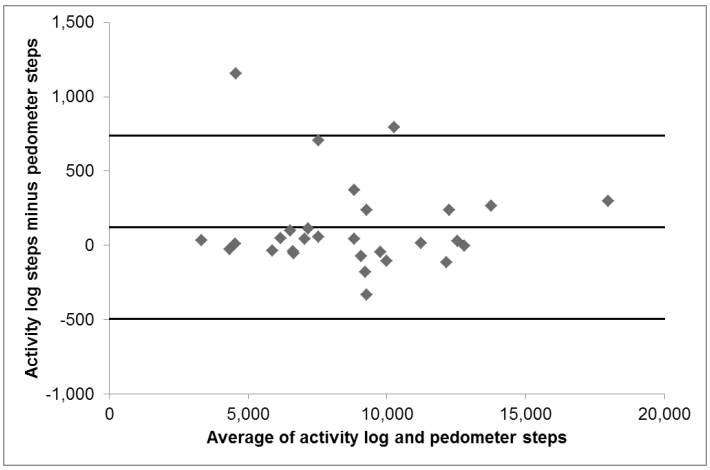

Figure 2: Bland-Altman plot comparing pedometer and activity log average daily steps. Horizontal lines represent average difference between pedometer and activity log, and lower and upper 95% limits of agreement.

Reliability

Reliability of step counts averaged over various lengths of time is plotted in Figure 3. Intraclass correlation coefficients (ICCs) for all observation periods exceeded 0.88, indicating good reliability. ICCs were similar for activity log and pedometer steps and monitoring for more than two or three weeks yielded only minimal improvements in ICC. These results suggest that despite the fact that most dog owners did not report 90 days of step counts, the reported step counts showed enough consistency from day to day that average daily step counts from both recording methods may be considered reliable, especially if averages are taken over a period of 2 weeks or longer.

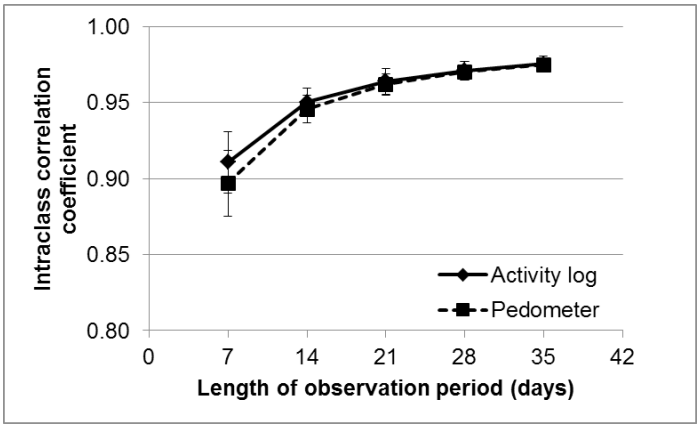

Figure 3: Intraclass correlation for average daily steps, by length of observation period. Error bars represent the standard deviation of ICC estimates based on N=8 observation periods.

Discussion

In general, agreement between the pedometer and activity log was good. Exact agreement on a day-to-day basis was rare, but averages over the entire study period tended to be similar, with an ICC of .99 and typical differences between methods of less than 9%. Pedometer and activity log data were similar with respect to internal reliability (ICC) for various observation periods.

About ten more days of data per person were obtained from the pedometer than from the activity log, but many of these "extra" step counts were suspiciously low, and likely represented days on which the pedometer was not worn. Users of electronic pedometer data should understand how such low step counts are handled by their pedometer software, and take action to remove or account for these values, since including them in overall averages could yield underestimates of typical physical activity.

Our observed compliance is roughly consistent with previous literature. Fukuoka et al. [2] found higher compliance (94% for pedometer, 88% for diary), but they observed subjects for only three weeks. They also found higher compliance with the pedometer than with a mobile phone diary, similar to our finding of higher compliance with the pedometer than the activity log. Zoellner et al. [32] reported that in a 6-month study, 85% of diaries and 73% of step counts were reported. Our activity log compliance (89% of activity logs submitted, including 80% of daily step counts) falls between the findings of Fukoka and Zoellner, as might be expected

since our 90-day duration is between their 3-week and 6-month studies. Rhodes et al. [19] conducted a study of similar length to this one and found 88% compliance, nearly identical to our 89%, although they asked dog owners to record step counts for three one-week periods rather than daily. Internal reliability was high for both step recording methods. Similar to the results observed by Kang et al, [33] we found ICCs exceeding 0.9 based on two or more weeks of consecutive monitoring.

Although dog owners were asked to wear the pedometer all day, they typically wore it for only about 13 hours. Anecdotally, participants reported taking off the pedometer before such activities as swimming, yoga and formal occasions, and sometimes forgetting to put it back on. Also, assuming that the average person sleeps between 7 and 8 hours in a 24-hour period and is awake for 16-17 hours [34] dog owners on average did not wear the pedometer for 16-21% of their waking hours. Therefore, recorded step counts (by both methods) are likely an underestimate of actual steps taken during a typical day. This would not affect comparisons between groups if the underestimate is the same in all groups, but will tend to underestimate physical activity.

On a daily basis, step counts from the pedometer and activity log rarely matched, but most differences were small. There were a few large discrepancies that primarily reflected problems with the pedometer and, in a few cases, transcription errors. Averaged over the 90-day period, steps per day differed by only 123 steps between pedometer and activity log, similar to the difference of 110 steps per day observed by Behrens et al. [6] averaging over eight days of observation.

Loss of information from the activity logs arises primarily from failure to fill it out daily (three dog owners did not fill out the log at all, one dog owner did complete the log however her dog destroyed the log and the data were treated as "missing"; and only 14% provided the requested 90 days of data), and to a lesser extent from recording errors. Pedometer errors were more common than expected, resulting in two complete failures and some days on which pedometer records were suspiciously low. Based on participation and completion in this study, to achieve the desired sample size of participants in future studies of activity levels of dog owners, enrollment should be increased by 6% in a study using electronic step counts to allow for pedometer failure. Enrollment should be increased by 11% in a study using logbook step counts to allow for noncompliance. Among dog owners who submitted any valid pedometer and activity log data, day-to-day compliance with the activity log was sufficient to yield reliable estimates of daily activity that corresponded closely to pedometer step counts.

Kang [33] suggested that 30 days of pedometer monitoring is sufficient to obtain valid and reliable estimates of "habitual" physical activity. Considering that pedometers failed to record at least 1,000 steps on 16% of days, and dog owners in this study failed to manually record steps in the activity log on an additional 4% of days, studies that rely on self-reported steps may need 38 days of monitoring to yield 30 days of valid data.

This study has several limitations. The dog owners in this study were primarily women, so the results may not be generalizable to men. Dog owners volunteered to participate in the study, so they may have been more motivated than the general public to comply with the study procedures. Reliability estimates for pedometer data pertain to the Lifecorder EX model and may not be generalizable to other models. Step counts are known to vary seasonally, which is not directly addressed in this study. However, we do not expect seasonal variation to affect differences between methods. A potentially important issue that cannot be addressed in this study is whether compliance with pedometer wearing would be different in a study that did not require concurrent activity log entries.

This study adds to the body of knowledge concerning reliability and accuracy of self-reported step counts based on pedometer readings, specifically as compared to pedometer-recorded step counts. Researchers designing studies of dog walking and physical activity can use these findings as a practical guide to determine whether self-report or pedometer-recording is more cost-effective for their study, and for planning additional days of monitoring for self-reported step counts to account for reduced compliance with this method.

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