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Step activity monitor: Long-term, continuous recording of ambulatory function

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Abstract—In many areas of research and medicine, objective data describing an individual's ambulatory function are sought as useful indicators of that person's condition. Normally, detailed measurements are taken over short periods of time within a controlled laboratory setting. To complement this approach, Prosthetics Research Study has developed a small, unobtrusive instrument that continuously records a simple measure–step counts per unit time–as an individual goes about normal daily life. The Step Activity Monitor (SAM) is approximately the size and weight of a pager and is worn at the ankle. It can detect steps with better than 99% accuracy across a wide range of gait styles for adults, children, and large animals. During monitoring, step counts are recorded at consecutive, adjustable time intervals over weeks to months at a time. Recording at 1-min intervals for a minimum of 2 weeks is recommended. Once monitoring is completed, the data are transferred to a computer, and the levels and patterns of step activity can be analyzed. This article provides a detailed description of the SAM, guidelines for use, results of accuracy and reliability testing, case study descriptions demonstrating the ability to measure differences that result from medical interventions or changes in health status, and a discussion of considerations pertinent to long-term monitoring of activity.

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INTRODUCTION

Objective measurements of the effects of medical interventions are gaining importance in healthcare. Clinicians, administrators, medical researchers, and third-party payers need to make decisions about the quality of care and the effectiveness of new medical treatments. Objective evaluations, often referred to as "outcomes assessment," are increasingly sought as the basis for these decisions.

The extent to which a person is able and willing to move around the world is often a strong indicator of his/her condition. Not surprisingly, formal or informal assessments of ambulatory function are commonly used as a clinical assessment tool. Frequently, a clinician will simply observe the individual walking into or around the examination room. Alternatively, patients are sometimes asked to report on themselves by filling out a questionnaire or responding to interview questions. Although these methods are quick and inexpensive, their inherent subjectivity can be problematic (1-5).

When more objective physical measures are needed, gait laboratories can furnish comprehensive descriptions of how an individual walks, albeit at considerable expense. Detailed analyses of aspects of gait, such as joint kinematics, ground reaction forces, electrical activity of muscles, or energy requirements of walking, provide a wealth of quantitative information. However, sometimes the mechanical and physiological details of how people *can* walk are not the only concern. When the primary question is how *much* subjects actually walk, gait laboratory testing is not the most appropriate investigational tool. An approach complementary to traditional testing methods is to monitor function as the person goes about normal daily life (6).

In the field of cardiology, long-term measures are routinely used in conjunction with short-term measures to provide complementary information. Twelve-lead EKG testing and Holter monitoring represent such a combination, in which neither component can take the place of the other. Analysis of the EKG gives detailed information about the electrical activity of the heart for a short period of time, but can miss many important arrhythmias or patterns seen only by looking at the heart activity over long periods of time. Continuous Holter monitoring provides the big picture for rhythm disturbances, and how they occur over time outside of the laboratory during daily activities.

While short-term measures of gait and musculoskeletal functionality are well-established in research and medical practice, long-term measures of physical activity have repeatedly been proposed as a means of obtaining meaningful, quantitative indicators of an individual's medical condition and/or physical status (7-12). In 1976, for example, Halstead proposed that continuous remote unobtrusive monitoring provides a more useful means of evaluating the success of rehabilitation programs than short-term, specific testing in highly controlled, standardized settings (6). To date, however, long-term monitoring has not been widely used for evaluating physical function or treatment efficacy.

A number of devices to measure physical activity over extended periods of time have been sporadically used for research and clinical evaluation. These include the Caltrac® Personal Activity Computer (13), which increments a unidirectional acceleration-based measure, and the Large Scale Integrated Activity Monitor (LSI), which increments a count based on movement-activated closures of an electronic mercury tilt switch (12). A major limitation of these devices is that they provide only a single, lump sum measure to represent the overall level of activity for the entire monitoring period.

Some commercially available monitors provide a time-based breakdown of data and, thus can capture changing patterns of activity. For example, the Motionlogger™ Actigraph (14) and the Tritrac® (15) both continuously record measures based on the three-dimensional acceleration at the attachment site. The Actigraph has two modes of operation: one records an event count (the number of times the output voltage changes sign), and the other records an accumulation of time spent above a threshold acceleration. The Tritrac records a measure of integrated acceleration that is used to calculate an estimate of caloric expenditure. The data recorded by these and similar devices have been very useful in the study of topics such as sleep disorders, circadian rhythms, hyperactivity, and Parkinson's disease. Their main drawback for issues concerning gait and mobility is that the unit of measure is difficult to equate directly with gait functionality. Warren W. Tryon prefaces his extensive summary of equipment used for measuring activity with the assertion that defining a basic unit of measure is critical to understanding any phenomenon under study. In the discussion of existing instruments, he contends, "It can be argued that the step is the preferred unit of measure [for activity monitoring] because it is a natural unit of ambulation" (14).

Daily step counts have occasionally been employed to assess the extent of prosthetic limb use (7,16,17) and the efficacy of various medical treatments such as hip joint replacement (10). Several researchers have designed step-counting instruments for specific applications. In 1979, Holden, Fernie, and Soto introduced a step-monitoring device consisting of a footswitch embedded in a prosthetic foot and a single-counter storage unit attached to the tubular pylon of an endoskeletal prosthesis (8). The storage unit was read once a day, and the pattern of variability in daily step totals was used to objectively evaluate progress in rehabilitation programs for persons with lower limb amputation. Two years later, H.J.B. Day designed a similar device and used daily step totals to validate an activity questionnaire (18). Both Holden's and Day's step-counting instruments are impractical for widespread use, however, because they require incorporation into a prosthetic limb.

Many pedometer-type devices are commercially available and can be worn by anyone. Both step counters and pedometers are normally worn at the waist, where vertical movements increment a single register. In the case of pedometers, the increments are scaled according to a selected stride-length setting. Accuracy has been reported to vary considerably between subjects (19,20) and to be particularly questionable for those with gait disorders (21). Frequently reported problems with both types of instrument include that the response is affected by factors such as movement style, walking speed, mode and location of attachment, and the amount of soft tissue at the attachment site. Following their investigation into pedometer accuracy, Washburn et al. (19,22) concluded that the results of their study and others reported in the literature "offer little to recommend the use of the mechanical pedometer."

In 1991, D.G. Smith proposed the development of the Step Activity Monitor (SAM) in order to overcome the limitations of the previously available long-term activity monitors. The main development goals were for the device to be easy to use, highly accurate, unobtrusive for the wearer, capable of continuously recording data in short time intervals, and capable of withstanding the demands of field monitoring (23).

METHODS

Monitor

The SAM (**Figure 1**) detects and counts steps for a wide variety of gait styles, ranging from a slow shuffle to a fast run. The monitor is approximately the size of a pager and was designed for long-term use without maintenance by the user. It measures 6.5 cm high x 5.0 cm wide x 1.5 cm thick (**Figure 2**), and weighs 65 g. The device consists of a sensor, surface mount electronics, and a battery, all fully sealed in a urethane case. The battery provides 4 to 5 yrs of continual use and is not replaceable.

To achieve maximum sensitivity for step detection, the SAM is worn just above the lateral malleolus on the right leg or the medial malleolus on the left leg. The inner surface of the SAM is curved with a 50-mm radius and can be padded if desired. The device is secured to the leg by two elastic attachment straps. Alternatively, the straps can be removed and the monitor worn in a soft cotton/lycra sleeve that fits loosely around the ankle. The SAM has successfully been used to

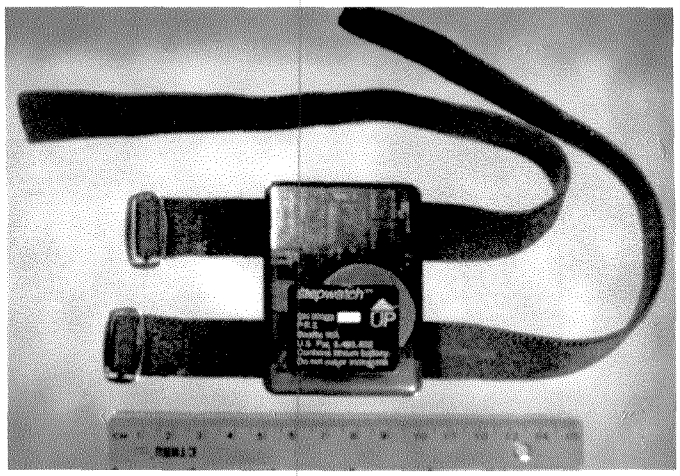

Figure 1.
Step Activity Monitor.

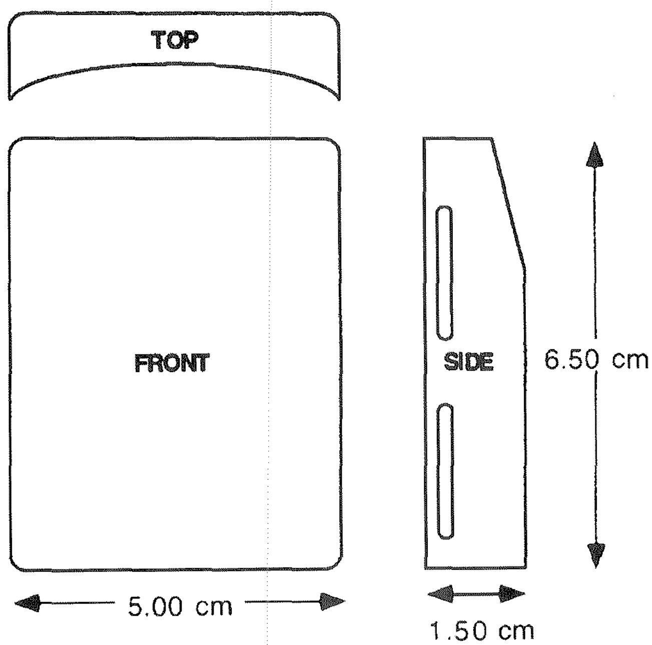

Figure 2.
Scale drawing of the Step Activity Monitor.

monitor adults, with and without gait abnormalities, children, and large animals. In over 7.5 person-years of monitoring time, including nearly 2 person-years accumulated on 65 subjects with compromised circulation, no problems or occasions of discomfort with wearing the device have been reported.

Sensor

The sensor, specifically developed for use in this instrument, consists of a custom accelerometer and an electronic filter to reject extraneous signals. The accelerometer was designed to consume very little power yet be acutely sensitive to the types of movement associated with a wide range of gait styles. The sensitivity of the sensor to *movement* can be adjusted through a software control called the "threshold" setting. Additionally, the sensitivity of the sensor for *step counting* can be adjusted by varying two electronic filtering parameters, the "cadence" and the "motion" settings. These parameters are adjusted using a personal computer running the SAM software each time the monitor is set up for use.

The *cadence* setting limits the frequency with which steps are detected. At one extreme, this setting will accommodate very high step rates but introduces the possibility of double-counting steps occurring at low rates. At the other extreme, very low step rates are accurately identified, but higher step rates will be under-represented. By choosing a setting appropriate for an individual's fastest and slowest step rates, accuracy is maximized for that range.

The *motion* setting determines how much acceleration is required for a step to be detected. For an individual who walks very dynamically (i.e., high angular and linear accelerations at the ankle), the sensitivity should be reduced to avoid false counts. For one who walks gingerly, the sensitivity should be maximized to avoid missing counts.

The effectiveness of the chosen settings is verified by visual inspection of a light on the device while the subject is walking. The light may be set to blink for up to the first 255 steps detected. If the light does not blink once during every step taken, the user can adjust the settings to improve accuracy. Accuracy exceeding 99 percent for normal walking should be expected for most subjects.

Memory and Sampling Interval

The SAM can store up to 16,128 intervals of data as 8-bit integers. The minimum time limit for monitoring is determined by this memory capacity and the duration of the selected recording interval. However, the effective limit for monitoring depends also on the level of inactivity of the subject being monitored, because a compression scheme is used for recording periods of inactivity (zero-count intervals). A minimum limit to the monitoring duration can be calculated (# days = 16,128 intervals • recording interval duration in minutes / 1440 min/day), and the actual limit can be estimated. In our experience, very few people are inactive less than 60 percent of the time. The least amount of inactivity we have recorded for a single day was 35 percent. If 1-min sampling intervals are chosen, for example, recording of step counts can proceed for a minimum of 11.2 days, and can conservatively (based on 30 percent inactivity) be estimated to continue for 14.5 days. Likewise, if 2.5-min sampling intervals are used, recording can proceed for a minimum of 28.0 days, and can conservatively be estimated to continue for 36.4 days. These approximates are extremely conservative, and monitoring can often proceed for at least twice the estimated time.

The minimum sampling interval is 6 s, which yields a minimum limit of 1.12 days. The maximum sampling interval is 25.5 min, which provides a 285.6-day minimum limit for continuous recording.

A second set of compression algorithms is built into the device to allow recording of step counts exceeding a value of 255 (the maximum value of an 8-bit integer) per interval. These should be invoked during set-up if the chosen recording epoch is so long that the maximum count for any interval might exceed 255.

Dock and Software

A personal computer is used in conjunction with a small, battery-powered docking unit to set up the SAM for monitoring and to transfer the data to a computer file after monitoring. The dock connects to the computer via a serial cable, communicating with the SAM through an infrared optical link to eliminate the need for cables or electrical connectors on the SAM.

To program the docked monitor, the user simply selects the desired options from the

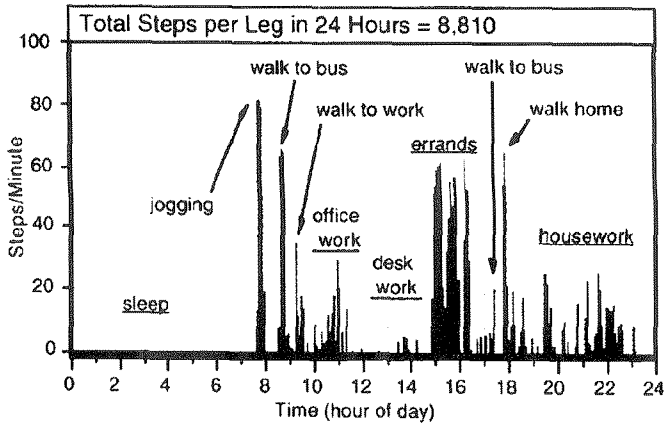

Figure 3.
Annotated step activity data for a single day.

computer screen, then directs the computer to perform the set-up programming, a routine that takes approximately 25 s. The SAM is then donned by the subject. When monitoring is complete, the same software is used to transfer the data from the SAM to the computer for analysis and long-term storage. Transferring time varies with the amount of data recorded, but generally takes between 30 and 60 s. The data are retained in the SAM memory and may be transferred again at any time until the SAM is reprogrammed for further monitoring.

RESULTS

Plotting the SAM data against time reveals distinct patterns of activity associated with the specific tasks or activities performed during monitoring. **Figure 3** illustrates a single day for which individual activities have been identified.

Measurement Sensitivity

The following case reports demonstrate how SAM can be used to detect differences in gait activity resulting from medical intervention/change in health status.

Case Report 1

The first intervention involved changing the prosthetic components of an active person with transtibial amputation from his normal dynamic limb to a traditional style, more rigid limb. The subject was monitored for 1 week with his normal limb, then switched to the rigid components and monitored for a second week. He was not told what type of components he had received, only that he had been switched to different ones.

The subject stated that he had done more walking on the second limb, even though he found the limb less comfortable. Despite feeling that he had walked more on the rigid limb, however, the data showed that during his normal weekdays he was more active with the flexible limb. With the dynamic limb, he took 40.1 percent more steps per day and consistently achieved higher peak step rates (**Table 1**). He spent 38.5 percent more time in moderate intensity activity and 7.9 percent more time in high intensity activity. Additionally, he spent an average of 1.4 more hours per day being active.

His weekend data showed much variability in both the levels and patterns of activity with each limb. Notably, his most active day occurred while he was wearing the rigid limb, when the weather and his schedule permitted him to play golf. The total of 11,227 steps per leg for that day (contrasted with the weekday averages of 5,191 and 3,705 steps with the dynamic and rigid limbs, respectively) indicates that the rigid limb did not ultimately limit his ability to function at a high level, but instead led him to make consistent daily choices to walk less during normal activities.

Case Report 2

The second intervention was an elective transtibial amputation for chronic pain and dysfunction of the foot and ankle arising from complications following a chondrosacroma. The patient, a 47-year-old female, was monitored for 1 week prior to the amputation, then for 1 week 18 months postamputation, after she had been fitted with a prosthesis. The results (**Table 2**) show dramatic increases both in overall level of activity and in time spent at higher activity levels. **Figure 4** depicts a single day from each condition.

Case Report 3

The third example documents the change in activity of a 56-year-old woman before and after congestive heart failure. The initial 2-week monitoring period began 4 weeks before heart failure. The second 2-week monitoring period began 2 weeks after heart failure, when she had returned to work and her "normal" routine. The overall results (**Table 3**) show clear decreases both

Table 1.
Results of pilot work using the Step Activity Monitor to evaluate differences in daily activity with two different prosthetic limbs for a person with transtibial amputation.

	Measure	Rigid Limb* Mean	Flexible Limb† Mean	Difference^
Weekdays	Total Steps	3705	5191	40.1%
	Hours of Inactivity	17.5	16.1	-8.0%
	Low Activity (hrs/day) ~	5.9	7.0	18.3%
	Mod. Activity (min/day)#	41.8	69.1	65.5%
	High Activity (min/day)§	12.9	14.4	11.1%
Tennis Days	Total Steps	5250	6766	28.9%
	Hours of Inactivity	15.5	15.6	0.6%
	Low Activity (hrs/day)~	7.0	6.5	-7.2%
	Mod. Activity (min/day)#	99.4	119.5	20.3%
	High Activity (min/day)§	5.8	24.5	325.0%
Weekends (incl. golf)	Total Steps	7273	4254	-41.5%
Weekends (w/o golf)	Total Steps	3319	4254	28.2%

*Rigid Limb: Otto Bock 30 mm aluminum pylon, titanium tube adapters, Otto Bock SACH foot;
†Flexible Limb: Seattle™ Air Stance pylon, Seattle™ LightFoot;
^Percent difference calculation: (Flexible Limb-Rigid Limb)/Rigid Limb;
~Low Activity = 1-15 steps/min;
Moderate Activity = 16-30 steps/min;
§High Activity = >31 steps/min.

Table 2.
Step activity summary measures for before and after elective transtibial amputation for pain.

	Pre-Amputation	Post-Amputation	Change
Average daily step total	2679	4502	+68.0%
Active time per day	6.1 hrs	8.1 hrs	+32.8%
1-15 steps/min/day	5.4 hrs	6.5 hrs	+20.4%
16-30 steps/min/day	39.0 min	63.2 min	+62.1%
>31 steps/min/day	4.0 min	33.4 min	+735%

in overall activity level and, particularly, time spent at higher activity levels. **Figure 5** depicts a single day from each condition.

Accuracy

Table 4 presents SAM accuracy data for 10 subjects with diabetes or lower limb amputation, who exhibited widely variant gait styles. The monitors were properly tuned for the gait style of each subject, who walked at self-selected velocity on level ground, uphill (9 percent grade), downhill (9 percent grade), and up and down stairs. Because the accuracy for walking on level ground was very similar to hill walking, the data from the three conditions were combined.

Overall step counting accuracy for normal walking was 99.7 percent. The lowest accuracy recorded for normal walking was 98.8 percent.

Table 4.
Step activity monitor step counting accuracy for 10 subjects with diabetes or lower limb amputation.

Sub	Age	Cond	Steps Walking Outdoors* Actual^	SAM	% Error	Steps on Stairs† Actual	SAM	% Error
1	68	D	430	435	1.16%	28	28	0.00%
2	56	DPN	607	607	0.00%	28	27	-3.57%
3	68	DPN	554	553	-0.18%	30	32	6.67%
4	59	DPN	473	473	0.00%	28	28	0.00%
5	68	DPN	453	454	0.22%	28	29	3.57%
6	68	TTA	723	721	-0.28%	30	29	-3.33%
7	47	TTA	518	519	0.19%	29	30	3.45%
8	55	TTA	466	468	0.43%	31	33	6.45%
9	62	TFA	514	512	-0.39%	27	29	7.41%
10	52	TFA	467	468	0.21%	31	32	3.23%
Average Deviation~					**0.31%**			**3.77%**

*Walking was performed outdoors on a sidewalk, on a course that included level stretches as well as uphill and downhill sections on a 9% grade;
†stair portion involved climbing and descending two flights of 12 stairs; Sub=subject; Cond=condition;
^Actual=step counts measured by two trained observers using hand-held tally counters;
~Average Deviation calculation: (S|%Error|)/n;
Abbreviations: D=diabetes; DPN=diabetes with peripheral neuropathy; TTA=transtibial amputation; TFA=transfemoral amputation.

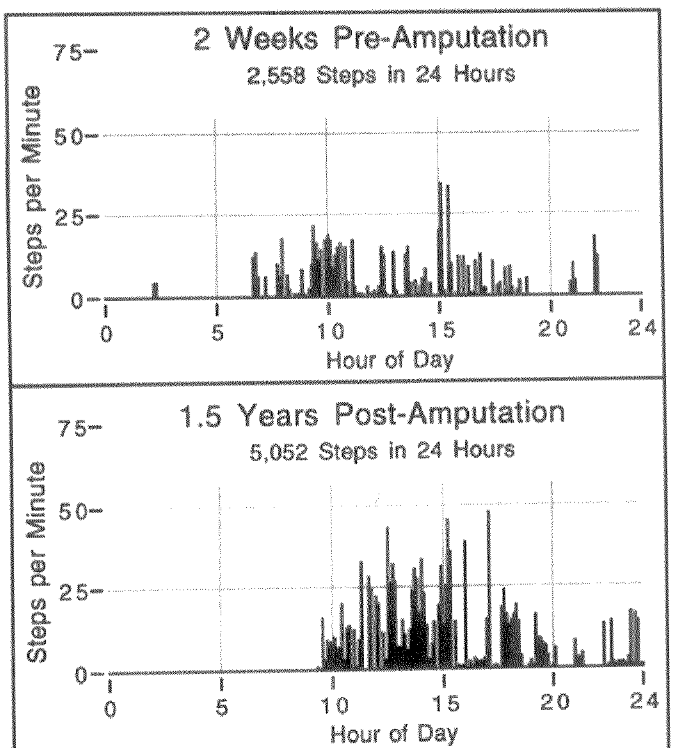

Figure 4.
Step activity data for sample days before and after elective amputation for pain.

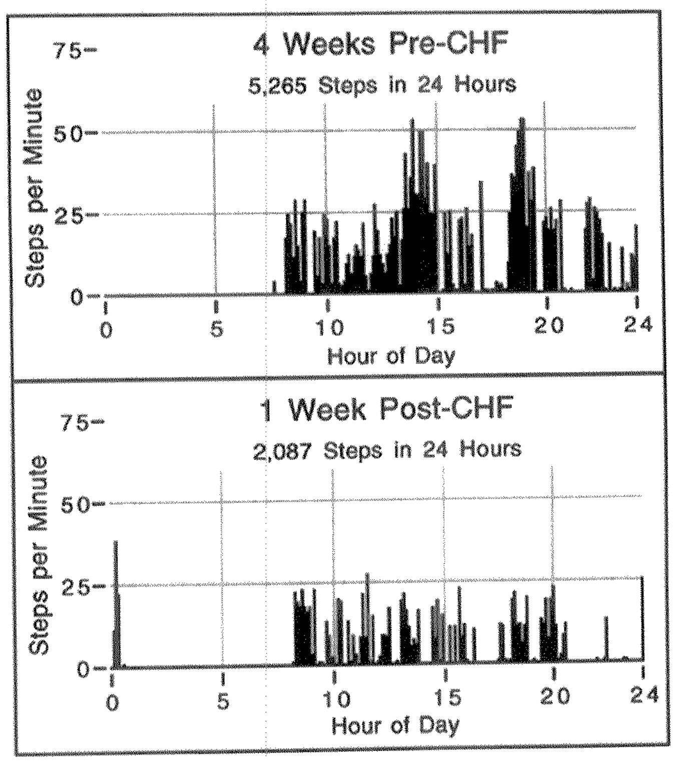

Figure 5.
Step activity data for sample days before and after congestive heart failure.

Overall accuracy for walking on stairs was 96.2 percent, where the SAM overcounted for six subjects and undercounted for two. Many of the subjects had difficulty negotiating stairs. Hesitations in movement and lack of fluidity on the stairs, uncharacteristic for the subjects during normal walking when the sensitivity settings were selected, produced the counting errors.

Reliability

Test-retest reliability data were collected with 45 subjects with diabetic peripheral neuropathy, both with and without amputation. Two accuracy trials over the same course were conducted for each subject, separated by a 2-week monitoring period. For each subject, the same monitor with the same sensor settings was used for both accuracy trials and the intervening 2-week monitoring period.

The trials were conducted on a test course that involved walking from the inside of a building, through a ground floor exit, turning to the left and traveling one city block along a level sidewalk, then turning around and returning to the starting point. The course was described to each subject before beginning each accuracy trial, and, if necessary, prompting was provided during the trial. Two observers with hand-held tally counters accompanied each subject on each trial. The mean of the observers' counts was used for calculating the accuracy of the SAM count.

Table 5 presents the test-retest data. The average deviation of the SAM count from the observers' count was 0.54 percent for Trial 1 and 0.65 percent for Trial 2.

DISCUSSION

Long-term monitoring necessitates many compromises to balance conflicting objectives. These include the level of detail of the data, duration of the monitoring period, size of the monitoring device and the resulting data set, level of involvement (thus daily awareness) of the subject, and choice of a unit of measure. The following discussion addresses some of these issues with respect to long-term step monitoring.

Time Resolution

Recording data in many short consecutive time intervals allows a more detailed description of the character of an individual's activity than does the accumulation of a single, lump sum measurement. **Figure 6** illustrates this point with a day of step data from two individuals. The subjects each took approximately 3,000 steps. If monitored with a simple pedometer–which yields a single step total–their data would appear equivalent. However, because the step counts were recorded in short, consecutive time intervals, one can see that the subjects exhibited very different patterns of activity. One subject accumulated the steps in an evenly paced manner throughout the day, while the other accumulated the steps in several large bursts of activity, separated by periods of rest. The individual activity patterns reflect how each subject moves in the world. Analysis of these patterns allows more complete descriptions of real-world gait functionality than is possible with assessments based on single-sum measures of long-term activity.

Table 5.
Test-retest reliability and accuracy of the Step Activity Monitor (n=45).

Variable	Trial 1	Trial 2
Average step count*	134	135
Average deviation of SAM count+	0.54%	0.65%
Minimum number of steps*	63	72
Minimum SAM count	62	71
Maximum number of steps*	187	189
Maximum SAM count	186	188
Total number of steps*	6031	6112
Total SAM count	6019	6084

*Step totals for comparison with the Step Activity Monitor measurements are means of counts measured by two observers using hand-held tally counters;
†Average deviation calculation: $(\Sigma|\%Error|)/n$.

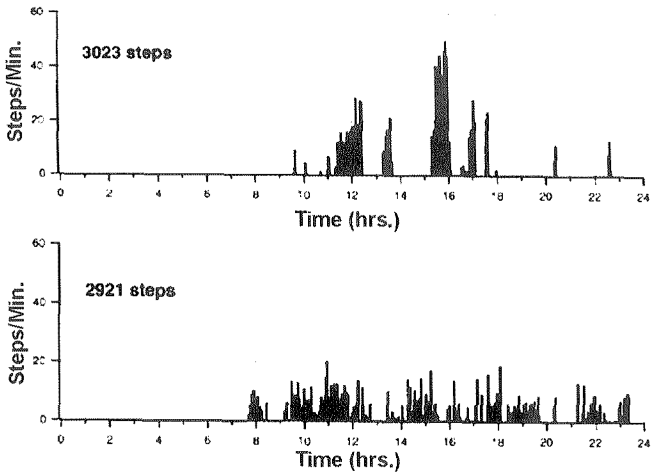

Figure 6.
One day of step activity data from two individuals, showing similar step totals but markedly different patterns of activity.

In choosing a sampling interval, a balance must be achieved between the level of detail with which activity is registered and how unwieldy the data and device are. For example, recording how many steps an individual takes each hour lends more insight into that person's activity than a single daily total, but fails to show details, such as the intensity of short bursts of activity or the pattern of rests the person took within the hour. Shortening the sampling interval to 1 min provides a more detailed picture of activity and rest periods, but requires 60 times the memory and more battery power than does recording at 1-hr intervals.

The duration of the sampling interval, or epoch, is particularly important when quantifying the intensity of activity, since the epoch represents the shortest time over which intensity measures can be calculated. The longer the epoch, the greater the chance that gait activity varied considerably within that period of time. Since the sole intensity measure that can be calculated for an epoch of SAM data is average step rate, any variations that were actually present within the epoch are lost. The use of 1.0-min epochs with the SAM allows continuous monitoring for several weeks and provides a reasonable balance between resolution and volume of data.

Length of Monitoring Period

In the typical routines of life, there are several repeating units of time that are notable. Each day has many distinct events, such as rising from sleep, morning hygiene, breakfast, lunch, dinner, or bedtime, each of which influences activity patterns. Common events, such as commuting to or from work, work-specific activity, recreational activity, attending church, exercise routines, or housecleaning chores, may not happen every day. Often these activities depend on whether or not one is employed. For subjects who are employed, a week frequently represents a key unit for monitoring, because the routines of work heavily influence overall activity patterns. At least 2 weeks of continuous data must be collected to observe whether this is the case for any individual. For individuals who do not work, some show extremely consistent activity patterns day to day; others appear unpredictable.

Figure 7 demonstrates the extent to which work can determine ambulatory activity. During the depicted monitoring schedule, the subject worked Tuesday through Friday the first week, and Monday through Thursday the second week. The monitor was removed at 11:20 A.M. on the second Friday. On work days, the overall activity level exceeded 3 times that of nonwork days, and peak step rates were consistently higher.

Unit of Measure, Data Scaling, and Other Considerations

Some caution must be taken to consider the "value" of a step when comparing pre- to postintervention step count data in the evaluation of treatment efficacy. For example, a change in prosthetic components might increase step length, thereby decreasing the number of steps needed to perform a given activity (24) or vice versa (25). If this is a concern, *and* if steps of different length are judged to have different worth, measurements of average step length are simple to collect and can be used to scale the step data. However, such scaling strategies must be considered carefully with respect to the subjects or conditions to be compared. In support of the unscaled step as a basic unit of measure, Warren W. Tryon writes, "Recall the fairly common scene of a parent crossing the street with his or her young child. The parent walks at a comfortable pace taking relatively few steps to cross the street while the child hurriedly takes many steps to keep up with the parent. I submit that the child was relatively more active than the

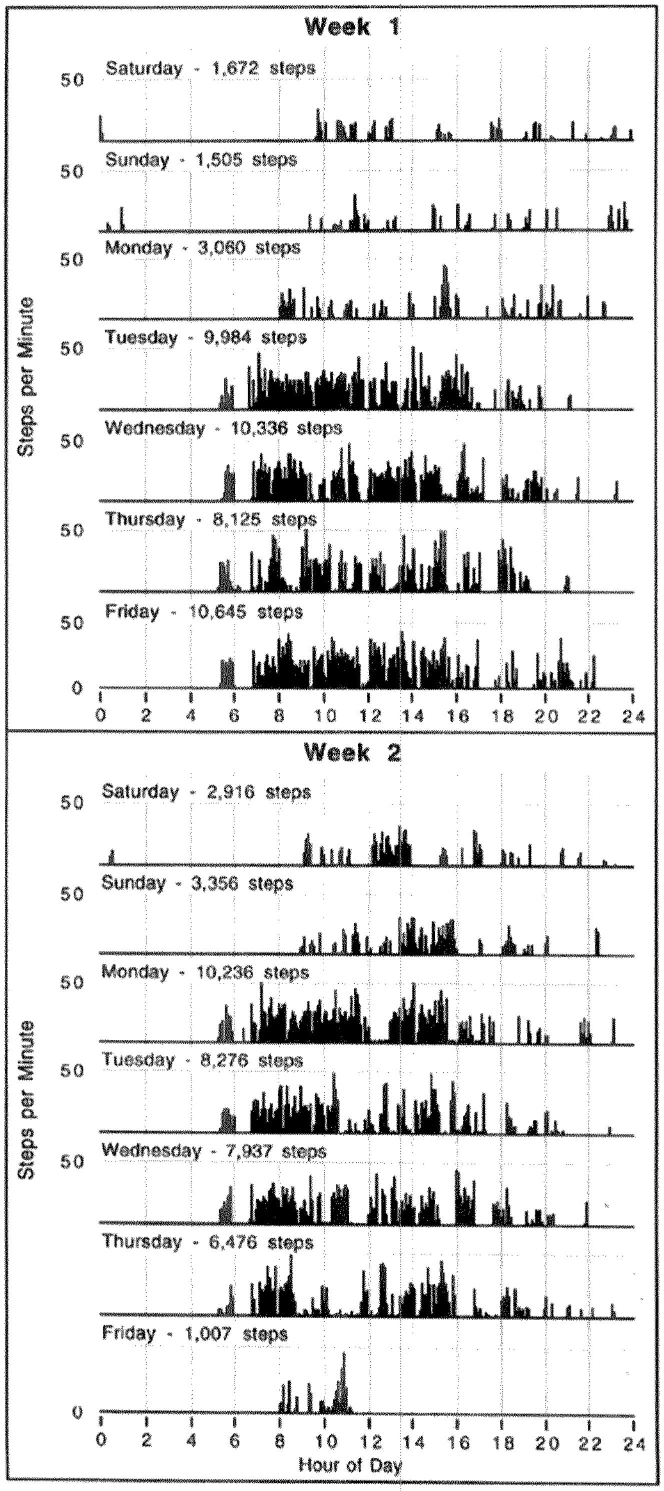

Figure 7.
Two weeks of step data from one subject showing distinctive differences in activity pattern between work and nonwork days. The subject worked 4 days per week (T-F, M-Th), leaving home at 6 A.M. and driving approximately 45 min. The monitor was removed on the last day of the second week at 11:20 A.M.

adult when crossing the same street and so should rightfully receive a higher score" (14).

If metabolic or mechanical loads are of concern, the relationships to step rates must be considered. As step rate increases, the metabolic and mechanical demands on the body generally increase in kind. However, this relationship varies across subjects, activities, and conditions. Although step rate data have a strong association with metabolic expenditure and mechanical stresses related to gait, the step activity data are geared to reflect mobility.

Identification of Specific Activities

The SAM measures the number of steps taken in each successive time interval, which is a measure of average step rate. Although many activities produce distinct, recognizable patterns of step accumulation, the step-rate data do not specifically define which activities were undertaken during monitoring. If such information is desired, the subject can maintain an activity log. After monitoring, the activity log and the step data can be combined using the time of day for reference. The SAM was designed to allow minimally intrusive monitoring so as to minimize possible behavioral changes in response to the feeling of being "observed." Maintaining a log greatly increases the subject's level of participation; thus, daily awareness of being monitored. Consequently, the likelihood of inducing "performance behavior" rises.

CONCLUSION

The continual recording of step counts in short time intervals is a viable means for monitoring a subject's gait activity outside of the laboratory during normal daily activities. The SAM is a highly accurate, reliable, ankle-worn instrument that can be used to perform long-term step monitoring on a wide range of subjects. SAM data reflect both the cumulative level and the minute-by-minute variations of step activity. These data can effectively quantify differences in ambulatory activity resulting from medical interventions and changes in health status.

In long-term continuous monitoring, it is important to choose an appropriate sampling interval for the recording and an appropriate length of time for the observation period. These permit meaningful analyses of levels and patterns of step activity, encompassing both the consistency and variability found in daily and weekly rhythms.

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