Evaluation of optimal sampling interval for activity monitoring in companion dogs

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Objective—To determine by use of an accelerometer the sampling interval that has the least variable total activity counts from one week to the next in companion (ie, nonlaboratory) dogs.

Animals—80 dogs.

Procedures—Dogs wore an accelerometer continuously for 2 weeks. Between-dog and within-dog day-to-day variability in total activity counts were evaluated. The changes in counts between week 1 and week 2 were compared for weekdays, weekends, and full weeks.

Results—Significant between-dog variability in total activity counts was detected. Within dogs, there was significant day-to-day variability, with highest counts recorded on weekends. In comparison of data from the first week with data from the second week, the greatest differences were in weekend counts (median difference, 21%; range, 0% to 154%) and the smallest differences were in full 7-day counts (median difference, 10%; range, 0% to 74%). Comparison of weekday counts revealed a median change of 12% (range, 0% to 104%).

Conclusions and Clinical Relevance—Significant between-dog variability in total daily activity counts was detected. Within dogs, a full 7-day comparison of total activity counts from one week to the next provided the least variable estimate of the dogs' activity. For dogs in their home environment, the activity monitor may be most useful in following changes in activity over time. For dogs that have no change in routine according to the owner's report, the least variable estimates of activity can be collected by comparing activity in 7-day intervals. (*Am J Vet Res* 2009;70:444–448)

There is increasing interest in evaluating how chronic disease may affect dogs through assessment of their behavior in their everyday environment.[1–4] Many chronic conditions can cause changes in a dog's activity. Conditions such as cardiac disease and osteoarthritis can compromise mobility, whereas a condition such as pruritus could increase an animal's activity.[1–4] An objective method of quantifying the activity of companion dogs in their routine environment could be a useful tool for monitoring progression of disease or the efficacy of a treatment . In addition, extent of activity directly affects an individual dog's energy balance and factors into that dog's caloric requirement, so an objective means of quantifying activity might also be useful for tailoring feeding recommendations to better reflect a companion dog's opportunity and inclination to exercise.

An accelerometer[a] has been developed that can continuously record the intensity, frequency, and duration of movement for extended periods. This device has been used to monitor the activity of laboratory dogs (principally Beagles) in several investigations.[5–8] One study, determining locomotor activity rhythms in laboratory dogs, revealed that the dogs' activity was dependent on their housing environment.[5] The size of the housing area and the type of facility (indoor vs partially outdoor) influenced the dogs' activity. Variability of environment is certainly an issue to consider if accelerometers are to be used as an objective measure of activity in companion dogs.

Companion dogs, in contrast to laboratory dogs, are generally housed in considerably different environments, which can vary substantially among individual households. Also, the daily routine of laboratory dogs is uniform regardless of the day of the week, unlike that of companion dogs, which may vary from day to day and could be influenced by the activities of their owners. In addition, the kinds of activity in which companion dogs participate are likely to be much more variable and uncontrolled in comparison to laboratory dogs. If the greater variability in the environment and routine of companion dogs led to greater variability in the counts delivered by the accelerometer during home activity monitoring, it would be difficult to use this device to monitor changes in response to an intervention because important changes may occur even when there is no intervention at all.

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Presently, this activity monitor has not been validated for use in companion dogs in their home environment for an extended period of time. A necessary step in this validation is to determine whether the activity counts delivered by this device are consistent from one sampling interval to the next in dogs that are in their routine home environment (ie, no nonroutine activities such as vacations, activities associated with house sitters, or activities associated with additions of new dogs). Before this monitor can be used to detect changes in dogs' activity associated with an intervention, the kind of changes in activity counts one could expect with no intervention must be known, so that the sampling interval that delivers the least variable activity counts from one assessment to the next can be used for future studies.

The purpose of the study reported here was to determine by use of an accelerometer which sampling interval provided the least variable total activity counts from one week to the next in companion dogs. We hypothesized that total daily activity counts recorded by an activity monitor[a] would be highly variable among individual dogs and that within a group of companion dogs, there would be significant day-to-day variability in total activity counts, which would be most pronounced on weekends when there is potentially more interaction with owners. We also hypothesized that the day-to-day variability could be overcome by comparing total activity counts in 7-day intervals.

Materials and Methods

Dogs—The protocol was fully approved by an institutional animal care and use committee. Companion dogs belonging to the staff, students, and clients of the School of Veterinary Medicine of the University of Pennsylvania were recruited to enroll in the study. All enrollees were determined to be healthy on the basis of a medical history and results of a physical examination and free of any clinically relevant orthopedic or neurologic disease.

Study protocol—Only potential participants whose owners anticipated no changes in the household's typical schedule (eg, no vacations or boardings) were included in the study. The activity monitor was placed on a collar and positioned ventrally on the neck of each dog. Dogs wore the activity monitor continuously for 2 weeks.

Monitors—Activity was recorded by use of an activity monitor,[a] which is a watch-size device that can continuously measure the intensity, frequency, and duration of movement. A detailed description of the monitor and how it works is reported elsewhere.[8] In short, this device includes an accelerometer that is sensitive to movement in all directions. A piezoelectric sensor generates a voltage when the device is subjected to a change in velocity per unit time. The voltage is converted to a digital value that is used to adjust a running baseline value that permits filtering out constant accelerations such as those caused by gravity. The current digital value is compared with the baseline value, and the difference from baseline is used to create a raw activity value for the measurement period (epoch). The epoch is determined by the investigator and can be set at 15-second increments up to a maximum of 1 minute. The raw activity value is converted by the associated computer software and reported as an activity count. For the present study, the accelerometer data epoch was set at 1 minute. Therefore, an activity count was generated for every 1 minute of monitoring.

Statistical analysis—Total activity count data were not normally distributed because some dogs had much higher total activity counts than the others. Those were typically dogs that were trained for agility or owned by people who routinely included their dog in their own exercise routine. Therefore, nonparametric methods of data analysis were used. The Kruskal-Wallis test was used to evaluate the between-dog variability as well as the day-to-day variability in daily total activity counts that occurred during the 2-week period. The absolute values of the percentage change in total activity counts that occurred between week 1 and week 2 were calculated for the weekday (Monday through Friday), weekend (Saturday and Sunday), and full 7-day week intervals. The Wilcoxon signed rank test was used to make comparisons among the changes that occurred in weekday, weekend, and full-week total activity counts. In addition to this evaluation of data for all dogs as a group, data for individual dogs were evaluated to determine what proportion of dogs had activity changes over a full range of possible activity-change cutoff points. To investigate how the comparison of weekday and weekend activity counts could be affected by the fact that this was a comparison of 5 days (weekdays) to 2 days (weekends), 2 consecutive weekdays were randomly chosen for this analysis as well. For all comparisons, values of $P < 0.05$ were considered significant. All analyses were performed with commercially available software.[b]

Results

Eighty dogs were recruited for the study. Median age was 4 years (range, 1 to 12 years). There were 35 females (31 spayed) and 45 males (39 castrated). Median body condition score on a scale of 9 was 5 (range, 3.5 to 6.5). Median weight was 23.2 kg (range, 2.7 to 46.4 kg). Twenty-seven (34%) dogs were mixed-breed dogs, and 53 were purebred dogs. In the purebred group, there were 6 Border Collies, 4 German Shepherd Dogs, and 3 each of Australian Shepherd Dogs, Labrador Retrievers, and Huskies. There were 1 or 2 dogs of 23 other breeds.

For the purpose of illustration, graphic representations of the activity data from a single dog were created. The 24-hour activity from a representative dog and the 7 day activity for that same dog were plotted **(Figures 1 and 2)**. Total activity counts varied significantly ($P < 0.001$) among dogs. Within dogs, there was significant ($P = 0.007$) day-to-day variability with the highest counts occurring on Saturday and Sunday **(Table 1)**. The percentage change in total counts from week 1 to week 2 was greatest when comparing the weekend intervals (median, 21% change; range, 0% to 154%) and the least when comparing the full-

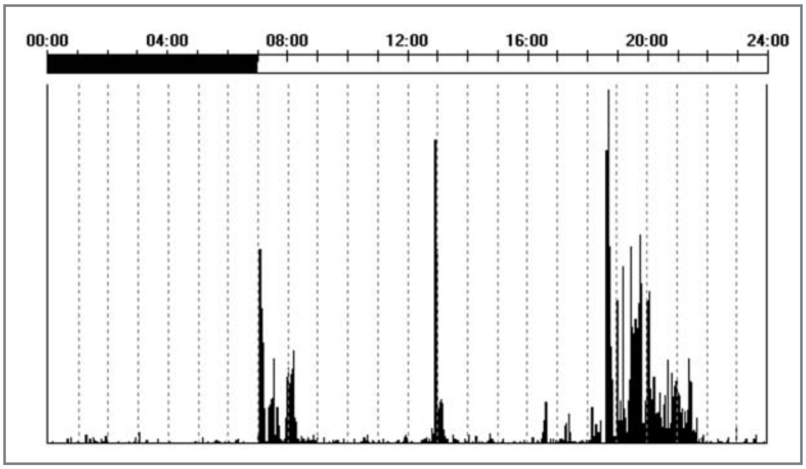

Figure 1—Graphic representation of results of a 24-hour period (midnight [00:00] to midnight [24:00]) of activity monitoring in a companion dog. Solid black bar indicates the period during which the dog was asleep.

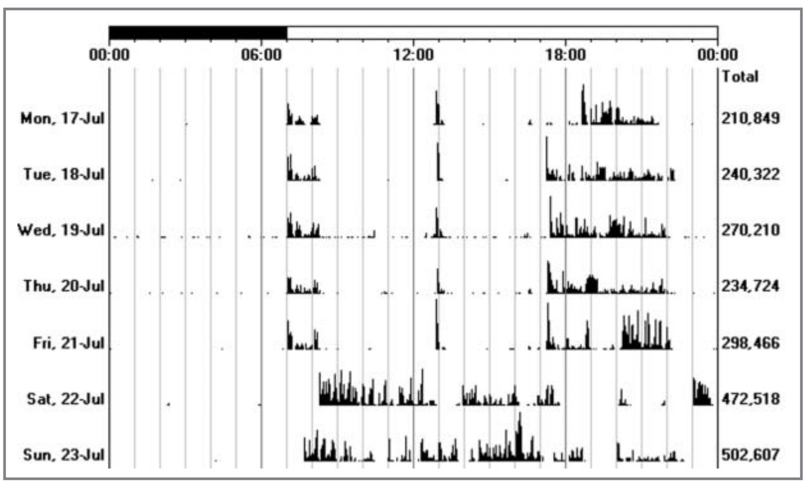

Figure 2—Graphic representation of 7 days of activity of the dog represented in Figure 1. In this household, the owner worked Monday through Friday and returned home at lunchtime to let the dog outside before returning to work again. Total = Total activity counts for each day. *See* Figure 1 for remainder of key.

Table 1—Median (range) total daily activity counts recorded in 80 clinically normal dogs continuously wearing an activity monitor for 2 consecutive weeks.

Day	Activity count
Mondays	182,076 (58,495 – 635,145)
Tuesdays	179,281 (62,268 – 767,268)
Wednesdays	187,478 (57,254 – 833,070)
Thursdays	174,696 (52,440 – 708,213)
Fridays	204,961 (52,760 – 750,630)
Saturdays	216,147 (57,338 – 827,354)
Sundays	231,335 (64,276 – 588,536)

week intervals (median, 10%; range, 0% to 74%). The change in total counts between the week 1 and week 2 weekday intervals revealed a median percentage change of 12% (range, 0% to 104%), and the median percentage change in Tuesday-Wednesday total counts from week 1 to week 2 was 17% (range, 0 to 107%). The percentage change in full-week counts was significantly less than the percentage change in weekday ($P = 0.03$) and weekend ($P < 0.001$) counts. The changes in weekend and weekday counts were also significantly ($P = 0.003$) different.

The proportion of dogs with changes in activity counts between week 1 and week 2 was determined over a full range of possible activity-change cutoff points, with weekend, weekday, and full-week interval changes represented separately (**Figure 3**). Across all cutoff points from at least a 10% change in total activity, there was a larger proportion of dogs with changes in weekend activity, compared with the weekday and full-week intervals. For example, for the 30% change cutoff point, 35% of the dogs had at least this degree of change in their total weekend activity counts between week 1 and week 2, whereas only 14% of dogs had this same change in total weekday activity counts, and only 7% of dogs had this degree of change in full-week total activity counts.

Discussion

This investigation found that when activity was recorded by use of an accelerometer in companion dogs, there was significant variation among animals. This is not surprising given the considerable range in environment and routines that exists among companion dogs. Given the high variability in activity counts among dogs, this type of device may not be appropriate for making cross-sectional comparisons among dogs but may best be used to follow changes in activity within individual dogs over time.

This study also revealed that companion dogs' total activity counts can vary considerably depending on the day of the week. This was not unexpected because a companion dog's routine may vary from day to day. It seems likely that a companion dog's activity would also be influenced by the owner's activities, which may differ depending on the day of the week. The dogs in this study had higher activity counts on weekends, which may reflect the greater likelihood that their owners were at home for interaction with the dogs. In addition, the weekend activity counts were typically the most variable, with most dogs having at least a 22% change in activity counts from one weekend to the next. This again may have to do with the variability in an owner's availability for interaction. We assume that most peoples' weekday routines are more consistent because of attending work or school than are their weekend routines.

Although week-to-week comparisons of weekday activity counts revealed less change than the weekend counts, the comparison of the full week of total counts from week to week appeared to give the least variable estimate of the dogs' activity when the owners reported that there were no changes in their dogs' routine. Because the goal was to determine which interval would

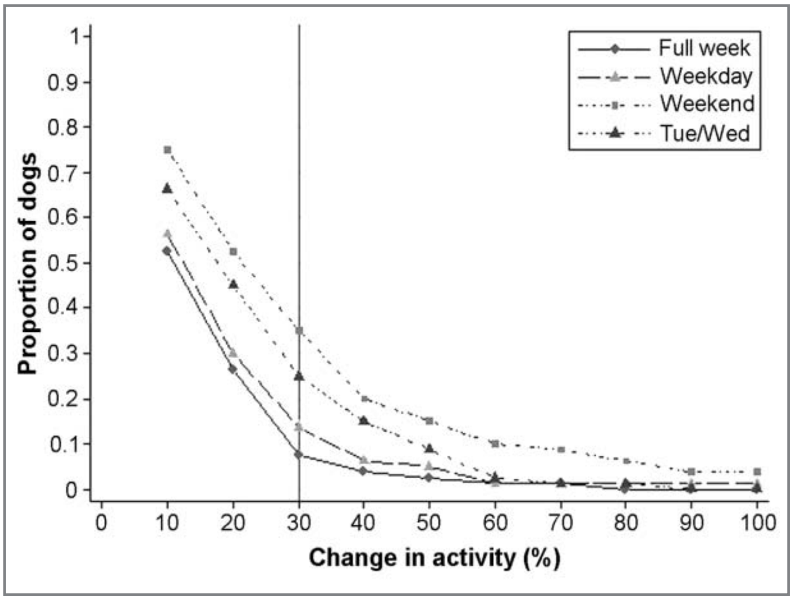

Figure 3—Proportions of clinically normal dogs (n = 80) that had various percentage changes in total activity counts from week 1 to week 2. Activity during the first week was compared with activity during the second week by use of 4 sampling intervals: weekdays (Monday through Friday), weekends (Saturday and Sunday), 2 weekdays (Tuesday and Wednesday), and the full 7-day week. The cutoff value of 30% is indicated with a solid vertical line.

be least variable from one week to the next, the direction of the change (ie, more vs less activity in week 1, compared with week 2) was not important and the percentage change was based on the absolute value of the change. Therefore, the change in total activity counts that occurred between weekends could be offset by a change that occurred in the opposite direction among the weekdays. Dogs could have unusually active days followed by unusually inactive days; therefore, the overall change during the full 7 days could be less than either of the 2 subset intervals because the changes in those intervals could be in opposite directions.

The full-week comparison gave the advantage of delivering the least variable estimate of activity from one week to the next while including the days of highest and most variable activity, the weekends. If one were using this device to follow the activity of dogs over time (eg, monitoring a change in activity in response to an intervention), excluding the weekend days from the comparison could mean that the days that are most likely to have a change and those with the highest activity (presumably because of increased owner contact) would be excluded. Use of a full 7 days for comparison of activity over time could avoid this potential pitfall. In addition, some owners may not have a typical schedule in which they are usually at work or school during the weekdays and at home on the weekends. Some people work weekends or variable shifts such that the days that they are most likely to be at home and able to interact with their dogs may not be weekend days. Use of the full 7 days of comparison between weeks allows those days of highest and most variable activity to be included in the comparison, whether they are weekdays or weekend days.

For this study, we did not collect data on owner activities. We only confirmed that the dogs' routine and the owners' routine were not expected to change during the 2 weeks of monitoring. If this activity monitor is to be useful as an outcome assessment tool for a dog's activity in its home environment, it must be reliable across a wide variety of environments and routines. If a dog's home environment or routine must be altered for the monitor to deliver consistent estimates of activity, its usefulness in companion dogs would be greatly diminished. In the group of dogs in the present study, the median change in week-to-week activity as determined by use of the 7-day interval was 10%. Assuming this degree of change can be expected over time in companion dogs that have no intervention will allow appropriate sample size estimation for future studies that use the monitor for determination of change associated with an intervention. Although these results are generalizable for dogs of both sexes and across a wide range of ages, breeds, and body conditions, all the dogs in this study were considered clinically normal on the basis of history and results of physical examination. If this accelerometer is to be used to monitor the routine activity of dogs with chronic health problems, further studies of the usefulness of this device in dogs with those specific diseases are warranted.

In addition, it is possible that an even longer sample interval, 14 days for example, might give less variable estimates of the dog's routine activity. The authors chose the 7-day interval because collecting baseline data for more than a week prior to randomization or intervention may not be practical for most studies. As the duration of the study increases, it may also become more likely for nonroutine events, such as holidays and vacations, to occur in the outcome interval, which could confound the data.

Until recently, studies[5–7] of activity monitoring in dogs have focused on laboratory dogs. Because those dogs have standardized routines and environments day to day, between-dog comparisons are possible.[5–7] A recent investigation[8] has revealed that the activity monitor can be used as an objective tool to measure a dog's activity in a less-controlled, homelike environment, but the inconsistency of the counts over time that might occur because of various physical household environments or owner interactions was not addressed.[8] Results of the present study suggested that a sampling interval of 7 days will provide a fairly consistent estimate of healthy companion dogs' routine activity while including the days of highest and most variable activity. Comparing 7-day intervals of activity over time in companion dogs could be useful in determining the efficacy of interventions or monitoring the progression of disease. Although further investigation is necessary, this device continues to have potential as an objective tool for measuring activity in companion dogs in the setting where they are found most often, at home with their owners.

a. Actical, Mini Mitter Inc, Bend, Ore.
b. Stata, version 8, StataCorp, College Station, Tex.

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