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Evaluation of the effect of signalment and body conformation on activity monitoring in companion dogs

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Abstract

Objective—To evaluate the effect of signalment and body conformation on activity monitoring in companion dogs.

Animals—104 companion dogs.

Procedures—While wearing an activity monitor, each dog was led through a series of standard activities: lying down, walking laps, trotting laps, and trotting up and down stairs. Linear regression analysis was used to determine which signalment and body conformation factors were associated with activity counts.

Results—There was no significant effect of signalment or body conformation on activity counts when dogs were lying down, walking laps, and trotting laps. However, when dogs were trotting up and down stairs, there was a significant effect of age and body weight such that, for every 1-kg increase in body weight, there was a 1.7% (95% confidence interval, 1.1% to 2.4%) decrease in activity counts and for every 1-year increase in age, there was a 4.2% (95% confidence interval, 1.4% to 6.9%) decrease in activity counts.

Conclusions and Clinical Relevance—When activity was well controlled, there was no significant effect of signalment or body conformation on activity counts recorded by the activity monitor. However, when activity was less controlled, older dogs and larger dogs had lower activity counts than younger and smaller dogs. The wide range in body conformation (eg, limb or body length) among dogs did not appear to significantly impact the activity counts recorded by the monitor, but age and body weight did and must be considered in analysis of data collected from the monitors.

There is increasing interest in assessing the behaviors of companion dogs in their routine environment, at home with their owners, and many of these behaviors are associated with a dog's degree of activity.^{1–3} Mobility and spontaneous activity can be altered such that owners notice a decrease in dog activity with conditions such as cardiac disease or osteoarthritis or an increase in dog movements with conditions that cause pruritus.^{2–5} An

objective method to assess the degree of activity in dogs in their typical environment could be useful for monitoring disease status or the efficacy of an intervention designed to treat a disease or its signs.

Activity monitors have been used to record locomotor activity rhythms in laboratory dogs (predominantly Beagles),⁶⁻⁹ and they can be used in companion animals to determine the efficacy of interventions or to monitor the progression of disease by comparing 7-day intervals of activity over time.^{4,10,11} In Beagles, age and housing environment can affect degree of activity.⁶⁻⁹ In companion dogs, the home environment affects activity as well. Dogs appear to have increased activity on weekends versus weekdays, presumably because of increased availability of owners for interaction.¹¹ To the authors' knowledge, the effect of age on the counts measured by an activity monitor in companion dogs has not been investigated.

An additional potential confounding variable in the assessment of degree of activity in companion dogs is body conformation. Various accelerometers have been extensively investigated as a means of monitoring physical activity in humans. Factors such as body type and locomotor characteristics are important sources of intersubject variation. Consequently, these devices must be validated for different populations (eg, children of various ages, adolescents, or adults).¹²⁻¹⁶ The intersubject variation reported for humans has implications for the use of accelerometers for monitoring activity in dogs given the enormous amount of natural variation in body length, body circumference, and limb length in this species. This aspect of activity monitoring in dogs has not been addressed in investigations that have involved laboratory subjects, presumably because of the uniformity of conformation among Beagles. However, it is important to know whether any aspect of signalment or body conformation could confound the results of activity monitoring in companion dogs if these monitors are to be used as an outcome assessment tool for evaluation of the presence, progression, or treatment of disease. If confounding variables are identified, they can be controlled for in the design and the statistical analysis of studies in which activity monitors are used.

The purpose of the study reported here was to evaluate the effect of signalment and body conformation on the outcome of activity monitoring in a heterogeneous group of companion dogs. Our hypothesis was that when given some control over the amount of effort involved in their activity (ie, trotting on stairs), older dogs would have lower activity counts than younger dogs. In addition, we hypothesized dogs with shorter limbs would have higher activity counts than dogs with longer limbs when performing the same activities.

Materials and Methods

Dogs

Staff and students of the School of Veterinary Medicine of the University of Pennsylvania were recruited to enroll their dogs in this study. To be included, dogs were required to be free of any clinically important orthopedic or neurologic disease according to history and physical examination. To ensure inclusion of a wide range of body conformations, at least 20 dogs were enrolled for each of the following 5 weight ranges: < 10 kg, 10 to 20 kg, 21 to

30 kg, 31 to 40 kg, and > 40 kg. The protocol used in this study was fully approved by the Institutional Animal Care and Use Committee of the University of Pennsylvania.

Signalment and body conformation measurements

For each dog, signalment data were recorded, including age, sex, and breed. Seven body conformation measurements were also made. Body weight (kg) was measured on a standard walk-on scale. Body condition score was assigned by use of a 9-point system (1 = cachectic, 4 to 5 = ideal, and 9 = morbidly obese).¹⁷ With the dog in a standing position, a standard tape measure was used to measure the circumference of the cranial aspect of the thorax at the level just caudal to the olecranon bilaterally; pelvic circumference was measured at the level just cranial to the tuber coxae of the ilium. Height at the shoulder was measured from the ground to the most cranial aspect of the greater tubercle of the humerus. Body length was measured from the midpoint between the cranial edge of the scapulae to the base of the tail, and stifle joint-to-hock joint length was measured laterally from the patella to the tuber calcanei. Two handlers made all of the study measurements. For the first 50 dogs, both handlers obtained independent measurements to test the inter-rater reliability of the measurements. For the subsequent 54 dogs, only 1 set of measurements was made.

Monitors

For all dogs, a commercially available activity monitor^a was used. The monitor is a watch-sized omnidirectional, accelerometer-based device that continuously measures the intensity, frequency, and duration of movement for extended periods. A detailed description of the monitor and how it works is reported elsewhere.^{9,18} In short, the monitor 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 of 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. One monitor was attached to the collar of each dog and positioned ventrally on the neck. The accelerometer epoch was set at 15 seconds to allow maximum data collection during each 3-minute activity period.

Activities

Each dog was guided through a series of standard activities. Data were collected for 3 minutes for each activity. Dogs were well acclimated to each activity prior to beginning the data collection and were given sufficient time between activities to completely recover prior to moving on to the next activity. Immediately before activities began, heart rate was measured and preactivity heart rates were compared to provide evidence of recovery between activities. The first activity was lying down; dogs remained in sternal or lateral

^aActical Activity Monitor, Philips Respironics Co, Bend, Ore.

recumbency for the entire data collection period. The second activity was walking; dogs were leash walked for laps along a designated smooth, level path. The third activity was trotting; dogs were trotted while on a leash for laps along a designated smooth, level path. Finally, the dogs trotted while on a leash up and down stairs along a designated path. The series of 10 stairs had a 15.2-cm rise/stair, and there was a 111.8-cm horizontal surface between each stair.

Statistical analysis

Descriptive statistics were calculated. Continuous data were expressed as mean $\pm$ SD when normally distributed or median (range) when not normally distributed. The weighted κ statistic was calculated to determine inter-rater reliability in the assessment of body conformation. Linear regression analyses were performed to evaluate associations of age, sex, and body conformation measurements with median counts for each activity. Univariate analysis was performed, and variables with a value of $P < 0.20$ were evaluated in a multivariable model. A given variable was retained in the multivariable model when the value of P for that variable was ≤ 0.05 or when its addition to the model changed the value of a coefficient for another variable retained in the model by $> 15\%$. To meet model assumptions, log transformation was applied to median activity counts prior to analysis. All analyses, including graphical analyses to evaluate model assumptions, were performed by use of commercial software.^b Values of $P \leq 0.05$ were considered significant.

Results

Dogs

One hundred four dogs were included in the study. The mean $\pm$ SD age was 4.9 ± 3.2 years. Fifty-eight (56%) dogs were male, and 46 (44%) were female. Breed distribution was as follows: 4 each of Boston Terrier, Border Collie, and Rottweiler; 3 each of Australian Shepherd, Boxer, German Shepherd, Golden Retriever, Jack Russel Terrier, Labrador Retriever, and Rhodesian Ridgeback; 2 each of Bernese Mountain Dog, Pomeranian, American Eskimo Dog, Great Dane, Pekinese, Scottish Deer Hound, Chihuahua, and Weimaraner; and 1 each of Afghan Hound, Anatolian Shepherd, Australian Cattle Dog, Beagle, Belgian Malinois, Border Terrier, Bulldog, Cairn Terrier, Greyhound, Miniature Schnauzer, Portuguese Water Dog, Pug, Silky Terrier, Whippet, and pit bull-type dog. The remaining 39 (38%) dogs were of mixed-breed.

Conformation measurements

Mean body weight was 25 ± 13 kg. Median body condition score was 5.5 (range, 4 to 8). Mean thoracic circumference was 66 ± 15 cm, and mean pelvic circumference was 50 ± 11 cm. Mean body length was 52 ± 14 cm, and mean stifle joint-to-hock joint length was 23 ± 8 cm. Mean height was 50 ± 16 cm. There was excellent inter-rater agreement for all conformation measurements ($\kappa \geq 0.9$; $P < 0.001$).

^bStata, version 10, StataCorp, College Station, Tex.

Activity counts

Fifteen-second epoch activity counts and heart rate measurements before and after 3 minutes of each activity were summarized (Table 1). Results of linear regression analysis for the lying down activity indicated 2 variables, height at the shoulder ($P = 0.13$) and body length ($P = 0.14$), met the criterion for inclusion in the multivariable model (ie, $P < 0.20$). Neither variable, however, was significant after multivariable modeling. Results of linear regression analysis for the walking activity also indicated 2 variables, body condition score ($P = 0.19$) and body length ($P = 0.17$), should be considered for the multivariable model, but neither variable was significant in that model. Results of linear regression analysis for the trotting activity revealed no variables met the criterion for inclusion in multivariable model.

Findings were different for the stair trotting activity. Results of linear regression analysis for that activity suggested 7 variables were eligible for inclusion in a multivariable model: age ($P = 0.04$), body weight ($P < 0.001$), thoracic circumference ($P < 0.001$), pelvic circumference ($P < 0.001$), body length ($P < 0.001$), height at the shoulders ($P < 0.001$), and stifle joint-to-hock joint length ($P < 0.001$). During multivariable model building, the value of P for all conformation variables exceeded 0.20 when the variables were added to a model containing body weight. Only age and body weight remained significant in the final model. There was a significant association between age and body weight with the activity counts such that when controlling for age, for every 1-kg increase in body weight, there was a 1.7% (95% CI, 1.1% to 2.4%) decrease in activity counts and when controlling for body weight, for every 1-year increase in age, there was a 4.2% (95% CI, 1.4% to 6.9%) decrease in activity counts (Table 2).

Discussion

Activity monitors have been used for several years to measure activity in laboratory dogs.⁶⁻⁸ Interest in using such monitors to measure activity in companion dogs in their home environment is more recent.^{4,9-11} There are some obvious fundamental differences in activity monitoring between laboratory and companion dogs. First, the environment of a companion dog can be highly variable and is likely affected by its owner's schedule. This is in contrast to laboratory dogs, which have a fairly regimented life with defined exercise periods and light-dark cycles. A second difference is that laboratory dogs are typically Beagles with somewhat uniform body conformation, so there has been no need, to this point, to investigate the effect of body conformation on activity monitoring.

With companion dog conformation ranging from that of a Chihuahua to that of a Great Dane, it is possible that limb length or some other body-size variable would affect a companion dog's movements and thus the activity counts recorded by the monitor. However, in the study reported here, this supposition was not always true. None of the body conformation variables evaluated in the present study affected the activity counts when the dogs were led through the controlled activities of walking laps and trotting laps. Although it may appear that short-limbed dogs or overweight dogs move differently when walking or trotting, compared with long-limbed or ideal-weight dogs, differences were not evident in the activity counts recorded by the monitor in our study. This might have been attributable to differences simply not existing or to the monitor being most sensitive in the direction

parallel with the longest dimension of the accelerometer case,⁹ which might cause it to pick up differences that predominantly exist in some other plane. Body conformation did affect the activity counts collected from the dogs as they were trotting up and down the stairs.

The activity of trotting up and down stairs was included in this study for 2 reasons. First, it got dogs moving in another plane that could affect the sensitivity of the monitor to movements. Second, it is an activity that is not as well controlled as the other 3. A Chihuahua-sized dog or an overweight dog could approach a 15.2-cm rise differently than a Great Dane-sized dog or a dog with an ideal body condition score. The dogs could also establish their footing differently along the horizontal surface before approaching the next stair. The distance between stair risers, however, ensured that all dogs climbed or descended all stairs individually; that is, larger dogs could not take > 1 stair at a time. Although one might expect body conformation to affect activity counts for this activity, the fact that it was body weight and not conformation that was identified in the statistical analysis was surprising.

Whereas body weight can be easily measured as an objective gauge of body conformation, in general, it is not a sensitive measure of the size or conformation of a dog. For example, a 15-kg dog could be an obese Pug or a fit Whippet. We hypothesized a priori that dogs with shorter limbs would have higher activity counts because of the extra effort needed to overcome the rise of each stair. However, the results suggested that, for this activity, body weight regardless of whether dogs were fat or thin or short or tall had the greatest effect on the activity counts recorded by the monitor. It is possible that a study involving a different cohort of dogs would yield different results; for example, if the same data were collected on 100 dogs, 50 of which were Great Danes and 50 of which were Bassett Hounds, perhaps a different body conformation variable that affects activity counts would be detected. Nonetheless, the populations in which the monitors are likely to be used are typically heterogeneous. Dogs with pain, cardiac disease, pruritus, and other conditions come in a wide range of shapes and sizes and not exclusively from opposite ends of the spectrum. This is generally true of age as well.

Although certain conditions may be more likely to develop in older dogs (eg, pain attributable to bone cancer), the definition of older can include a span of many years and the increase in years can affect the activity counts reported by the monitor. When all dogs were required to perform the same activity such as walking or trotting laps, age did not affect activity counts. However, when there was leeway in the activity for the dogs to approach their task slightly differently, which was possible in their approach to the stairs, as dog age increased, activity counts decreased. This may have been because younger dogs have a greater energy or rebound in their step, which is picked up by the monitor when they perform this type of activity or because older dogs may lose that movement because of a decrease in stamina. Regardless of the reason, the finding that age affected activity counts was not unexpected because the same has been found in laboratory dogs. During routine activity in the laboratory setting, puppies have significantly higher activity counts than young dogs, which in turn have higher counts than old dogs.⁸

When results of the study reported here are considered as whole, one can conclude there are at least some activities in which a dog's age and body weight may affect the activity counts measured with an activity monitor. Therefore, these factors need to be considered in studies in which these monitors are used to measure outcomes. Such factors can be addressed in the design of the study through methods such as stratification or matching, and they can be controlled for statistically in the analysis of the data. Activity monitoring has good potential as an outcome assessment tool for investigating many conditions in companion dogs, and understanding which factors can potentially confound the results of such studies allows investigators to control those factors and obtain more valid results.

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Abbreviation

CI Confidence interval

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Table 1

Mean (95% CI) 15-second activity counts and median (range) heart rates before and after 3 minutes of various standardized activities in 104 companion dogs.

Activity	Preactivity heart rate (beats/min)	Activity count	Postactivity heart rate (beats/min)
Lying down	92 (64–172)	10 (7–12)	88 (52–156)
Walking laps	88 (52–156)	292 (273–312)	100 (60–160)
Trotting laps	92 (60–140)	809 (758–860)	108 (68–220)
Trotting stairs	92 (52–152)	895 (818–972)	112 (72–180)

Table 2

Results of a multivariable linear regression model to evaluate factors affecting activity counts in 104 companion dogs trotted up and down stairs for 3 minutes.

Variable *	Coefficient	<i>P</i> value †	95% CI
Age (y)	−0.042	0.003	−0.069 to −0.014
Body weight (kg)	−0.017	0.001	−0.024 to −0.011

* To meet model assumptions for linear regression, the activity count data were log transformed. In such models, the format for interpretation is that activity counts change by $100 \times (\text{coefficient})$ percent for a 1-unit increase in age or weight.

† Values of $P \leq 0.05$ were considered significant.