Accuracy of the use of triaxial accelerometry for measuring daily activity as a predictor of daily maintenance energy requirement in healthy adult Labrador Retrievers

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Objective—To determine accuracy of the use of triaxial accelerometry for measuring daily activity as a predictor of maintenance energy requirement (MER) in healthy adult Labrador Retrievers.

Animals—10 healthy adult Labrador Retrievers.

Procedures—Dogs wore an accelerometer for two 2-week periods, with data on daily activity successfully collected for 24 to 26 days. These data, along with body weight, were used as independent variables in a multiple linear regression model to predict the dependent variable of daily MER. The predictive accuracy of the model was compared with that of a model that excluded activity. Dietary energy intake at a stated amount of body weight stability was used as an equivalent measure of MER in these analyses.

Results—The multiple linear regression model that included body weight and daily activity as independent variables could be used to predict observed MER with a mean absolute error of 63.5 kcal and an SE of estimation of 94.3 kcal. Removing activity from the model reduced the predictive accuracy to a mean absolute error of 129.8 kcal and an SE of estimation of 165.4 kcal.

Conclusions and Clinical Relevance—Use of triaxial accelerometers to provide an independent variable of daily activity yielded a marked improvement in predictive accuracy of the regression model, compared with that for a model that used only body weight. Improved accuracy in estimations of MER could be made for each dog if an accelerometer was used to record its daily activity. (*Am J Vet Res* 2011;72:1151–1155)

The maintenance of a healthy BW requires that an appropriate amount of energy is consumed to meet the basal metabolic needs of an animal and to replace the energy the animal expends during physical activity. This MER is calculated in dogs as an exponential function of BW, adjusted by a constant that is related to a subjectively determined amount of typical daily activity. However, there is considerable between-dog variation with regard to the amount of typical daily activity. For example, the National Research Council provides recommendations ranging from 95 kcal•kg of $BW^{0.75}$ for inactive pet dogs to 200 kcal•kg of $BW^{0.75}$ for active pet Great Danes.[1] Investigators in 1 study[2] found that activity constants ranged from 65.1 to 119.6 in 55 pet dogs that maintained BW (within 2%) over a 10-week period. Investigators in another study[a] found that activity constants ranged between 60.8 and 197.6 in 48 pet dogs that maintained BW (within 10%) over a 12-month period. Hence, the variation in individual MER is attributable, at least in part, to differences in the activity of individual dogs. The National Research Council acknowledges this by including the caveat that the 2006 maintenance energy guidelines should be considered only as a starting point for the assessment of the requirements for each dog.[1]

Abbreviations

BW	Body weight
MER	Maintenance energy requirement
RER	Resting energy requirement
VM	Vector magnitude

The ability to accurately record activity in dogs and to incorporate this information into predictions of daily MER would provide a means by which owners could better establish the correct food ration for their pets. However, it should be mentioned that the accuracy of existing predictive equations for use in estimating RER is poor, with individual requirements reported to vary between 48 and 114 kcal•kg of $BW^{0.75}$.[1] Therefore, the ability to separately characterize the activity component of MER and to use it to refine predictive models would provide only a small step toward removing the disparity between predicted and actual MER. Nonetheless, improvements to predictive equations for MER are a desirable goal because the prevalence of obesity in the

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dog population in studies[3,4] conducted in various regions of the world has been estimated as 20% to 40%, which suggests that a large proportion of dogs are routinely overfed, compared with their individual MER.

Considerable data on humans are available to suggest that triaxial accelerometers, which record acceleration in all 3 orthogonal planes, provide an accurate record of movement and are useful tools in the prediction of daily MER.[5–7] More recently, such devices were found to be suitable for in-home monitoring of activity in dogs.[8,9] Consequently, the opportunity exists to use accelerometers as a means of quantifying the amount of activity in dogs and to use these data to calculate the individual MER in a more objective manner. This is in contrast to the current situation whereby recommendations are made for subpopulations of animals on the basis of subjective assessment of activity.

The purpose of the study reported here was to investigate the amount of activity, as determined by use of a triaxial accelerometer, as a predictor of MER in healthy adult dogs. Our hypothesis was that the inclusion of activity data from an accelerometer could improve the accuracy of predictive models of MER constructed solely on the basis of BW.

Materials and Methods

Animals—Ten adult Labrador Retrievers were used in the study. All dogs were owned by the WALTHAM Centre for Pet Nutrition and cared for by personnel at that institution. Dogs were included in the study on the basis of their ability to maintain stable BW. Weight stability was assessed in 34 adult (< 18 months old) Labrador Retrievers at the WALTHAM Centre for Pet Nutrition for 10 weeks. Dogs with the lowest variability in BW during this 10-week period were selected for inclusion in the study. The dogs comprised 7 neutered males and 3 neutered females. Dogs were 1.6 to 10.7 years old (median, 5.6 years). The BW at the start of the study ranged from 26.0 to 33.1 kg (median, 29.1 kg). All dogs were housed in kennels in pairs and took part in typical husbandry routines (including daily access to an external exercise area and regularly scheduled walks on a leash) throughout the duration of the study.

All dogs were fed a nutritionally complete dry diet throughout the course of the weight-stability assessment and data collection periods of the study. Proximate analyses for the diet revealed that it contained 6.6% protein, 6.1% fat, 1.6% crude fiber, 8.1% fat, and 10% moisture. No adverse responses to the diet, such as vomiting or diarrhea, were observed.

Veterinary examinations were performed on all dogs prior to the start of the study to ensure that they were in good overall health. The study was approved by the WALTHAM Centre for Pet Nutrition Ethical Review Committee.

Accelerometer—A prototype triaxial accelerometer, designed and manufactured at the WALTHAM Centre for Pet Nutrition, was used to record mean daily activity of the dogs. The device consisted of a 3-axis piezoelectric linear inertia motion sensor[b] that stored data from each axis to a 128-MB reduced-size multimedia memory card via a microcontroller.[c] The accelerometer had a range of $\pm 2 \times g$, and data were logged at 10 Hz. Data from the device were downloaded and processed to filter out the static component (gravity) from each axis. These data were then processed to provide a single value of VM (square root of $[x^2 + y^2 + z^2]$) for each 0.1-second interval and were summed over 1-minute intervals to provide a value of VM per minute. Data were subsequently summed over successive 24-hour periods (1,440 separate values) to provide a value of total activity per day. Mean daily activity was then assessed in each dog over the data collection period by use of the daily total VM values.

Experimental design—All dogs wore an accelerometer for two 2-week periods, which has been determined as the time period suitable to provide sufficient data to enable determination of typical daily activity.[9] The accelerometer was attached to an adjustable fabric dog collar[d] that was worn by each of the dogs throughout the course of the study. Adjustments were made to the tightness of the collar, such that an index finger could be placed between the dog's neck and the collar. Thus, the potential effects of collar tightness among dogs on the data collected by the accelerometer were minimized.

The first day of each 2-week period was used to prepare the accelerometer and attach the collar; hence, there was a maximum of 13 days of data collection for each 2-week period (maximum of 26 days of data collection for each dog during the study). The 2-week collection periods were separated by an interval of 4 days to enable data to be downloaded and stored. Diet analyses were performed to allow accurate calculation of calorie density.[e] Body weight was recorded once each week during each 2-week study period, and daily energy intake of each dog was recorded. Because the dogs taking part in the study were of stable BW, energy intake was considered to be equivalent to MER.

Statistical analysis—A stepwise multiple linear regression model was used to describe the relationship between the dependent variable MER (equivalent to energy intake at stable BW) and the independent variables BW, activity, sex, and age. These independent variables were included following a backward-selection procedure; variables were removed if they did not have a significant ($P \leq 0.05$) effect on the dependent variable MER. The model was fitted according to ordinary least squares. All statistical analyses were performed by use of data analysis and statistical software.[10,f]

Results

Median amount of daily activity for each dog was 47,151 activity units (range, 24,198 to 65,754 activity units). Daily activity was calculated for data collected over 26 days for 7 dogs; infrequent malfunctioning of the accelerometer resulted in data collection over 25 days in 2 dogs and over 24 days in 1 dog.

Median within-dog coefficient of variation for BW in the 10-week period leading up to the onset of the study was 0.86% (range, 0.40% to 2.90%). During the 32-day study period, median within-dog coefficient of variation for BW was 0.74% (range, 0.38% to 3.11%).

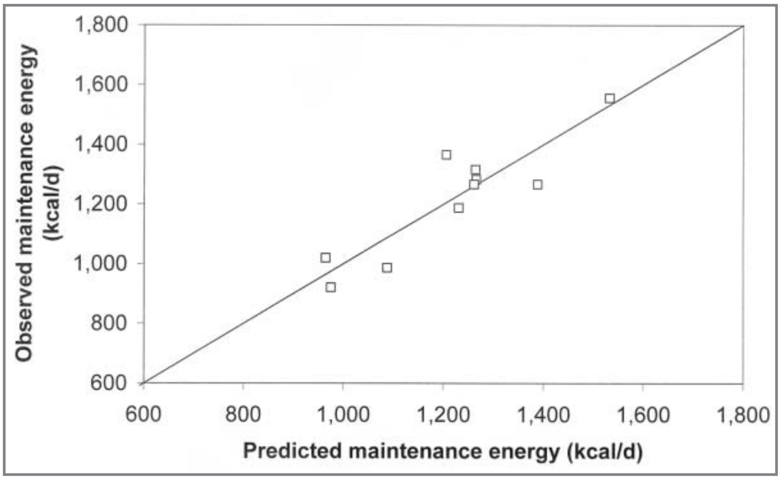

Figure 1—Observed versus predicted MER for 10 healthy adult Labrador Retrievers for a predictive model that includes BW and activity as independent variables. Each square represents results for 1 dog. The line indicates equivalence, with the vertical distance above or below the line indicating the difference between the observed value and the value predicted by use of the model. The mean absolute error is 63.5 kcal, and the SE of estimation is 94.3 kcal.

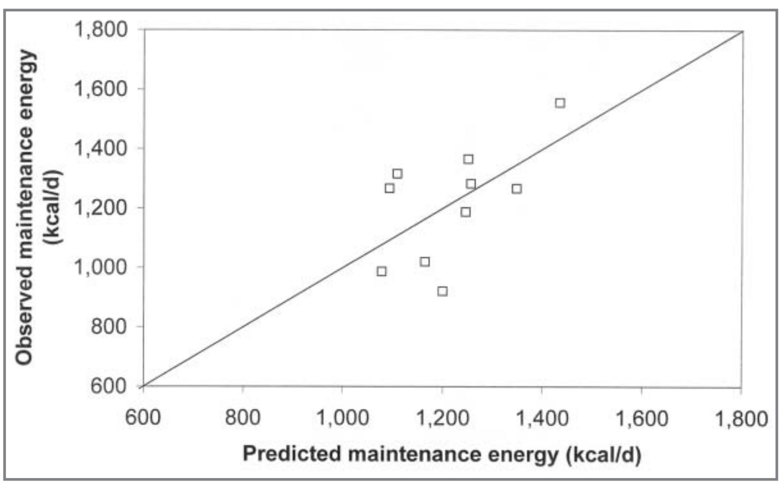

Figure 2—Observed versus predicted MER for the same 10 healthy adult Labrador Retrievers as in Figure 1 for a predictive model that includes only BW as an independent variable. Each square represents results for 1 dog. The line indicates equivalence, with the vertical distance above or below the line indicating the difference between the observed value and the value predicted by use of the model. The mean absolute error is 129.8 kcal, and the SE of estimation is 165.4 kcal.

Energy density of the diet was calculated in accordance with the equation of Kienzle et al[11] and was found to be 330 kcal/100 g.

Median MER (calculated on the basis of dietary intake) was 1,267 kcal (range, 921 to 1,556 kcal). The RER was calculated in accordance with an interspecies estimate[12] of 70 kcal•kg of $BW^{0.75}$, which yielded a median RER of 880 kcal (range, 815 to 972 kcal). Therefore, the energy expenditure of activity for each dog was estimated as MER – RER, which yielded a median value of 360 kcal (range, 51 to 584 kcal).

Exploratory statistical analysis revealed that data for the predictor variables (BW, activity, sex, and age) were normally distributed, variance of the residuals was constant over the observed range, and the predictors were independent (no covariance). Therefore, the data were appropriate for multiple regression analysis, with any slight deviation from the aforementioned tests attributed to insufficient data being available to make a definitive judgment.

A significant association was detected between MER and BW (P = 0.01) and between MER and activity (P = 0.01). No significant association was found between MER and age (P = 0.20) or between MER and sex (P = 0.74). Use of a predictive model that included BW and activity as independent variables explained 76.2% of the variability in MER (R^2 adjusted on the basis of the number of *df*). This model yielded an absolute mean error of 63.5 kcal and an SE of estimation of 94.3 kcal. The equation of the fitted line was as follows:

$$\text{MER} = (61.3103 \bullet \text{BW}) + (0.00998611 \bullet \text{activity}) - 1{,}032.67$$

Data for this analysis were plotted as observed versus predicted values **(Figure 1)**.

For comparative purposes, use of a predictive model that included only BW as an independent variable explained 26.8% of the variability in MER (R^2 adjusted on the basis of the number of *df*), with a mean absolute error of 129.8 kcal and an SE of estimation of 165.4 kcal **(Figure 2)**.

Discussion

The objective of the study reported here was to use a triaxial accelerometer to determine daily activity in healthy adult dogs and to investigate the effect of including this variable in a predictive model of daily MER. Analysis of the results suggested that inclusion of activity in a predictive model of daily MER led to an improvement in predictive accuracy. However, predicting MER remains imprecise, with the refined equation used in the present study accounting for only 76% of the variability.

Daily energy intake can potentially be used as an approximate measure of daily MER, provided that the BW of the dogs evaluated remains stable and there are no changes in husbandry. Stability of BW for the 10-week period preceding the start of the study was maintained until completion of the study. The overall variation in BW over the course of the study was low (within-dog coefficient of variation, approx 1%), which allowed an assumption to be made regarding the equivalence of daily dietary energy intake and daily MER. This enabled us to conduct the study without the requirement of performing complex and potentially costly energy expenditure measurements.

In general, collection of accelerometer data was successful, with only a small number of device malfunctions, which were likely attributable to transient damage during more vigorous bouts of activity. All such malfunctions were detected and rectified within 24 hours, thus allowing data recording to resume. Despite these short-term interruptions in data recording, a minimum of 24 days of accelerometer data was collected for all dogs, and 26 days of accelerometer data were available for 7 of 10 dogs. Investigators in 1 study[9] reported satisfactory results for data collection over a 7-day period in pet dogs, with most of the variability in data collected on weekends. However, a median difference of 10% (range, 0% to 74%) for the activity counts for the entire 7-day period was also reported.[9] Consequently, the study reported here was designed to collect data over a longer time period to provide a more robust mean value that better reflected the typical activity of each dog.

A predictive model that included only BW was used to predict mean daily energy requirement with a mean absolute error of 129.8 kcal, compared with the observed value. For a typical dry diet with an energy density of 330 kcal/100 g, this would equate to an error of approximately 39 g/d. Adding activity as a variable improved the predictive accuracy of the model such that the mean absolute error was reduced to 63.5 kcal, compared with the observed value. For a diet with an energy density of 330 kcal/100 g, this would equate to an error of approximately 19 g/d. On the basis of these calculations, the accuracy of the predictive model was greatly improved by the addition of activity as a predictive variable. Despite this, the amount of error in the refined predictive equation remains problematic. An owner committed to feeding their dog an appropriate amount of calories to maintain a healthy BW is likely to achieve at least as much success by monitoring and adjusting the dog's ration according to observed changes in BW. Further refinements of the predictive model, particularly refinements relating to the component of RER, would be necessary for it to become sufficiently accurate to provide an improvement in the owners' ability to feed their pets appropriately. As such, the improvement in predictive accuracy gained by the inclusion of activity in the model is an important step.

It is probable that the predictive accuracy of both models would be improved by the inclusion of a measure of lean body mass. Because muscle tissue is more metabolically active than is fat tissue, the use of BW as a predictive variable of mean daily energy requirement is a simplification because it does not differentiate between these 2 tissue types. However, given that the study included only dogs of a single breed with a weight range of 7 kg that were assessed as being in good body condition, the potential improvement in the model by inclusion of a measure of lean body mass may be only modest. Making an assessment of lean body mass is also a complex process, and accurate methods are not likely to be available outside a research environment. A practical solution from a dog owner's perspective would be to include sex as a predictive variable because males generally have a higher proportion of lean body mass, compared with that in females.[13] Further research is needed to investigate differences between males and females because the study reported here was not designed to determine effects of sex on predictive accuracy.

In addition to a lack of measure of lean body mass, there are other limitations of the study reported here. For example, although BW stability was maintained within a narrow range throughout the course of the study, more subtle changes in BW may have been apparent over a longer time period. Hence, the equivalence of energy intake and energy expenditure is not absolute, which thus introduces a level of error in the independent variable of MER used in the predictive model. Other sources of error not accounted for in the study design may have included the effect of animal age and temperament on MER. Overall, the study was limited to dogs of a single breed, all of which were neutered and living in a kennel environment. Therefore, the ability to extrapolate these findings to a wider population of pet dogs is limited. For example, the accuracy of a single-axis pedometer in assessing steps taken by dogs at a walking pace is affected by the size of the dog, resulting in overestimation of the number of steps taken by large dogs and underestimation of the number of steps taken by small dogs.[14] This clearly suggests that the data obtained by use of triaxial accelerometers may be affected in a similar manner; therefore, dogs of various sizes should be assessed in any attempt to derive a broadly applicable predictive model of MER. Similarly, further research to determine the impact of wider ranges of the amount of activity on models for estimating MER is likely to provide substantial improvements in predictive accuracy. Nonetheless, the data of the present study represent an initial step, which indicates that the use of triaxial accelerometers to provide data that can be used to improve the prediction of daily MER in pet dogs merits further investigation.

In the prediction of MER in the present study, a model that included a measure of activity provided a marked improvement in predictive accuracy, compared with results for a model that relied solely on BW. Hence, more accurate estimations of MER could be made for individual dogs by use of accelerometers to record the amount of activity, which provided a necessary step in the evaluation of the energy requirements of this companion animal species. Furthermore, the ability to assess activity would be of considerable usefulness in clinically affected animals for which adequate energy intake is in question, and it could be used to differentiate between inadequacy attributable to malabsorption or maldigestion or as a result of unusually high amounts of physical activity.

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