Feeding Practices of Pet Dogs and Determination of an Allometric Feeding Equation

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INTRODUCTION

The energy requirement and intake of dogs in the United States represent an important consideration for veterinary practitioners and pet owners. The amount of food that a dog receives each day ultimately impacts body condition, weight, and overall health. Today, excess energy intake (leading to conditions of overweight and obesity) is considered the most common nutritional disorder of pet dogs. Between 20% and 44% of adult dogs in the United States are considered to be overweight or obese.1-3 Most of these dogs are adult animals in their prime years, and only a small proportion are immature or elderly.4 Underweight conditions in healthy dogs are much less common and are usually seen in response to feeding a diet with low palatability, a sudden change in the dog’s activity level, neglect, or pathologic states.

While many dog owners are capable of determining how much to feed their dog to maintain optimal body weight and condition, a substantial proportion of owners inaccurately identify ideal body condition for their dogs and those with overweight dogs tend to believe that their dog is at a proper body weight.5,6 It is also possible that some owners are unwilling to admit that their pet is overweight, and so owner-reported surveys may underestimate the proportion of animals who are overweight or obese.7 Examining the ways in which owners

CLINICAL RELEVANCE

This study indicates that measuring caloric intake data of dogs in homes is achievable and can provide a practical and appropriate methodology for determining energy needs. This knowledge can be helpful in developing appropriate guidelines for pet food labels.
feed and live with their dogs may provide insight into the reasons that owners overfeed (or underexercise) their dogs and thereby promote overweight conditions. Several studies have reported that many dog owners regularly feed table foods and treats to their dogs, even though the majority feed a commercially available dog food as the dog’s primary diet. Therefore, any assessment of feeding dogs commercial foods and their effect on body condition must also account for dog owners’ tendency to include table scraps, biscuits, and treats in their dog’s diet.

In the United States, pet foods that carry a “complete and balanced nutrition” claim are required to include feeding instructions on the pet food label. While these instructions are intended as guidelines, their usefulness to the owner and their ability to accurately predict the needs of the average dog are important. Moreover, it is in the best interest of pet food companies to print practical estimates on their bags, since the success of these guidelines can affect consumer satisfaction with their product. However, determining exact daily energy needs of dogs is a complex task because of wide variations in the size, body conformation, living environment, activity level, and age of pet dogs. Dogs demonstrate the widest range of adult size of any domesticated species, with adult weights spanning a range of 100-fold difference between the smallest and largest breeds.

Academicians and nutritionists have published several different equations for estimating the maintenance energy requirement (MER) of dogs. Although there continues to be some disagreement about which equation best represents the majority of dogs, nutritionists generally agree that an allometric equation that converts body weight to an estimate of metabolic body weight most accurately accounts for the wide range in body size among dogs. Controversy revolves principally around the constant (K) that is used to adjust for activity and the value of the exponent that should be used to determine metabolic body weight (between 0.64 and 0.88).

The first objective of the study reported here was to measure whether adult dogs of varying breeds, selected randomly from different locations and fed in a home environment in accordance with feeding guidelines of an adult maintenance commercial pet food as supplemented in the regular course by the owner, gained, lost, or maintained weight. The study assessed actual daily caloric intakes of healthy adult dogs living in homes. Dogs were fed according to the feeding instructions on a commercial pet food bag while also fed the treats and table scraps that their owners were accustomed to providing. The effects of this practical, in-home feeding regimen on body weight (BW) and body condition score (BCS) were evaluated, and the potential influences of a dog’s age and size as well as the owner’s feeding practices were assessed. The second objective of the study was to use caloric intake and weight data for dogs that maintained body weight during the 10-week study to calculate a best-fit equation to provide estimates of MER of companion dogs living in homes.

**MATERIALS AND METHODS**

**Selection of Subjects**

The study was conducted at five different locations in the United States: Columbus, OH; Appleton, WI; Seattle, WA; Tempe, AZ; and Houston, TX. To obtain an initial pool of potential study subjects, dog owners were identified through random phone calls using a standard marketing screening tool. The screening tool included questions about the number of dogs in the home; the dog’s age, sex, breed, size, and activity level; the current pet food

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that was fed; and the type of feeding regimen used. Homes with one adult dog between the ages of 1 and 7 years (Figure 1) were accepted in the study. Selected dogs represented a variety of sizes and breeds (including breed mixes).

All dogs were identified by their owners as being normally active and were currently being fed a commercial dry dog food as their principal diet (i.e., 7 days per week, with canned food added only as a treat or for a special occasion). They were also meal fed, with owners providing a specific volume or weight of food one or two times per day. Dogs that were fed ad libitum or those receiving a therapeutic diet prescribed by a veterinarian were not included in the study.

Dog owners were between 21 and 70 years of age, were not involved with dog breeding or showing, and were neither employed directly nor related to an employee of any companion animal-related business. Ultimately, a group of 204 dogs was recruited for the study and attended the first weigh-in. Of these dogs, 19 were deemed ineligible due to initial BCS ≤ 2.5/5 (12 dogs), behavior problems (two dogs), or the owner’s decision not to continue in the study (five dogs).

Study Design

All dogs began the 10-week study between February 22 and March 5, 2001, and completed the study between May 8 and May 20, 2001. Regardless of the brand or type of food that was fed prior to the start of the study, all dogs were switched to the same commercial food (Iams Chunks or Mini-Chunks, The Iams Company) at the start of the 10-week feeding period. In addition to receiving free food for the duration of the study, owners were provided with monetary compensation ($200 total) upon study completion to further encourage compliance with the study protocol.

The amount each dog was fed was calculated by an impartial evaluator, using the dog’s current body weight, the allometric equation Kcal/day = 99 × (BW kg)0.67, and the metabolizable energy (ME) content of the commercial food (380 kcal/cup). This number was rounded to a common measuring cup interval. These calculations are in accordance with the feeding guidelines provided on the food’s label. The daily food volume was adjusted as needed to comply with the feeding guidelines each time the dog was weighed by study evaluators (bi-weekly). Owners were specifically instructed to continue to feed all other foods and treats as they normally would for the duration of the study.
Daily food diaries for each dog were recorded throughout the 10-week period. Spaces were designated on the form for owners to record the amount of dry diet that was offered, the amount consumed, and complete descriptions and quantities of all other dog biscuits/treats and human foods that were offered and consumed by the dog. Dogs were weighed using the Befour Inc. Scale (Model VSO700T)\(^b\) and BCSs were assessed by trained, impartial evaluators at the start of the study and biweekly throughout the 10-week period. Evaluators were trained to assess BCS in dogs by a veterinarian or veterinary technician during the first weigh-in at each location. Evaluators used a standard visual reference chart to assess BCS using the following five-point scale: 1 = thin; 2 = underweight; 3 = ideal; 4 = overweight; 5 = obese (dogs were assessed using 0.5 gradations).

A 2-week supply of food was given to owners at the start of the study and at each biweekly assessment. At each of these times, food diaries and instructions for feeding and recording data were reviewed with owners by the trained evaluators.

### Caloric Intake

The daily energy intake of each dog was calculated by totaling calories contributed by the volume of dog food consumed and calories contributed by recorded dog biscuits/treats and extra human foods over the entire study period. This total was divided by the number of days the dog remained in the study to provide a value for mean caloric (kcal) intake per day. The ME value of the commercial food (380 kcal/cup) was determined by the manufacturer through metabolism trials in which fecal and urinary energy losses were directly measured. Energy values for dog biscuits/treats were obtained either from the pet food label or directly from the manufacturer. When exact values for biscuits/treats were not available, an ME value for a comparable treat of similar size and type was substituted. Energy values for human foods were obtained from human food tables provided by the USDA Nutrient Data Base for Standard Reference.\(^b\)

### Data Analyses

Data were analyzed statistically using SPSS statistical package, version 11.5 (SPSS, 2002). Analysis of variance (ANOVA) was used to examine the potential effects of location (city),

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\(^b\)Befour Inc., Saukville, WI; capacity 500 lb, accuracy within 0.10 lb; scales were calibrated by the manufacturer before the start of the study period.
feeding practice, age, and size category on measurements of BW and BCS. When a significant main effect was found, pairwise contrasts (least significant difference) were used to further examine differences. Pearson’s chi-square test was used to examine differences between expected and observed frequencies of dog and owner characteristics among locations. A paired t-test was used to test for differences in BW and BCS over the 10-week period. A linear regression model described the relationship between metabolic BW and maintenance energy needs and provided best-fit equations for estimating MER in dogs that maintained weight.

## RESULTS

### Dogs

A total of 185 dogs began the study. Of this group, 12 dogs did not complete the study as a result of owners dropping out for unknown reasons (five dogs), submission of incomplete feeding diaries (four dogs), discovery that a dog was on medication (one dog), recurring behavior problems (one dog), and complaint of a dog being hungry (one dog). In addition, two dogs were removed after 8 weeks due to the perception of excessive weight loss. Upon further review of the data, however, it was found that other animals lost similar amounts of weight. To be more inclusive, these two animals were used in the final data analyses. The overwhelming majority of dogs (97%) completed 67 or more days of the study.

The dogs included in the study ranged in size from toy (5 to 14 lb) to giant (89 to 150 lb), with the majority (70.0%) weighing 16 to 75 lb and at least 15 dogs within each size category (Figure 1). As mentioned, dogs were between 1 and 7 years of age (mean: 3.73 years), with 2- and 3-year-olds representing the largest age categories (Figure 2).

A wide range of breeds and breed mixes were represented (Table 1). Of the 173 dogs that completed the study, 33.5% were categorized as a mixed breed of some type by their owners or breed was not recorded. Labrador retrievers (n = 19), golden retrievers (n = 16), beagles (n = 8), and cocker spaniels (n = 7) were the most common purebreds. Male and female dogs were equally distributed (46% male, 54% female), and 86% of the dogs were neutered. At the start of the study, independent evaluators found 89 dogs (51%) to be at their ideal body weight (BCS of 3.0 or 3.5/5), while 60 dogs (35%) were assessed to be slightly or moderately overweight (BCS of 4.0 or 4.5/5) and 24 dogs (14%) were considered obese (BCS of 5.0/5).

### Intake Data

The majority of owners (78.0%) fed their dogs the prescribed amount of commercial food each day plus various amounts of dog biscuits/treats and/or human foods. Thirty-eight owners (22.0%) fed only the prescribed amount of commercial dog food each day, with no extra dog biscuits or human foods.
Mean commercial dog food caloric intake per day tended to be higher in Group 1 than in the other three groups. Differences between groups in terms of calories contributed by biscuits/treats or human foods are as expected within feeding practices (Table 2). However, dogs in Group 4 consumed significantly more calories from biscuits/treats than did dogs in Group 2 (79.1 kcal vs. 59.2 kcal; P < .05).

### Body Weight and Body Condition Score
Mean initial BW for the entire group (n = 173) was 52.88 lb, and mean final BW was 51.75 lb (Table 3). Overall, dogs lost a mean of 1.14 lb over the course of the 10-week study, a percent change in BW of −1.49%. Mean initial BCS was 3.68/5 and mean final BCS was 3.49/5, with a mean change of −4.89%. Sixty-three dogs (36.42%) gained weight during the study, 10 dogs (5.78%) finished the study at exactly the same weight at which they had 1). Conversely, 48 owners (27.7%) fed their dogs varying amounts of dog biscuits and treats but no human foods (Group 2), 30 owners (17.3%) fed varying types and amounts of human foods but no dog biscuits/treats (Group 3), and 57 owners (32.9%) fed some combination of dog biscuits/treats and human foods (Group 4). These four feeding regimens were designated “Feeding Practices” and were included in further data analyses (Table 2). Analysis of the daily food diaries for each dog revealed that owners fed a large variety of brands of dog biscuits/treats and many different (and unusual) foods that are typically considered to be “human” foods.

Feeding practices of owners did not differ among the five study locations (Pearson’s chi-square test; P > .05), nor did the feeding practices of owners differ among different size categories of dogs (Pearson’s chi-square test; P > .05). Mean total intake per day did not differ significantly among feeding practice groups (Table 2).
TABLE 3. Effect of Feeding Practice, Age, Location, and Size on Body Weight (BW) and Body Condition Score (BCS)

<table>
<thead>
<tr>
<th>Dogs</th>
<th>Initial BW</th>
<th>Final BW</th>
<th>% BW Change</th>
<th>Initial BCS</th>
<th>Final BCS</th>
<th>BCS change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kg; mean)</td>
<td>(kg; mean)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Entire group (n = 173)</td>
<td>52.88 ± 2.22</td>
<td>51.75 ± 2.15</td>
<td>−1.49 ± .38</td>
<td>3.68 ± .054</td>
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</table>

**Feeding Practice**

<table>
<thead>
<tr>
<th>Group</th>
<th>Initial BW</th>
<th>Final BW</th>
<th>% BW Change</th>
<th>Initial BCS</th>
<th>Final BCS</th>
<th>BCS change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n = 38)</td>
<td>60.68 ± 4.83</td>
<td>58.80 ± 4.69</td>
<td>−3.00 ± 0.73</td>
<td>3.97 ± 0.11a</td>
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<tr>
<td>Group 2 (n = 48)</td>
<td>51.43 ± 3.86</td>
<td>50.15 ± 3.76</td>
<td>−1.84 ± 0.84</td>
<td>3.62 ± 0.11b</td>
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<tr>
<td>Group 3 (n = 30)</td>
<td>50.35 ± 5.36</td>
<td>49.40 ± 5.1</td>
<td>−0.97 ± 0.98</td>
<td>3.72 ± 0.13ab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 4 (n = 57)</td>
<td>50.24 ± 4.05</td>
<td>49.62 ± 3.91</td>
<td>−0.47 ± 0.56</td>
<td>3.50 ± 0.08b</td>
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</tr>
</tbody>
</table>

*Group 1 = dog food only; Group 2 = dog food + biscuits/treats; Group 3 = dog food + human foods; Group 4 = dog food + biscuits/treats and human foods.

**Location**

<table>
<thead>
<tr>
<th>Location</th>
<th>Initial BW</th>
<th>Final BW</th>
<th>% BW Change</th>
<th>Initial BCS</th>
<th>Final BCS</th>
<th>BCS change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appleton, WI (n = 38)</td>
<td>51.51 ± 4.43b</td>
<td>50.25 ± 4.36b</td>
<td>−1.88 ± 1.04</td>
<td>3.43 ± 0.08a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbus, OH (n = 32)</td>
<td>57.00 ± 5.10b</td>
<td>55.95 ± 4.92b</td>
<td>−1.14 ± 0.74</td>
<td>3.59 ± 0.14a</td>
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</tr>
<tr>
<td>Houston, TX (n = 36)</td>
<td>36.22 ± 3.96a</td>
<td>35.54 ± 3.88a</td>
<td>−1.20 ± 0.78</td>
<td>3.64 ± 0.11a</td>
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<td></td>
</tr>
<tr>
<td>Seattle, WA (n = 34)</td>
<td>60.36 ± 4.91b</td>
<td>58.52 ± 4.55b</td>
<td>−1.95 ± 0.77</td>
<td>3.69 ± 0.10a</td>
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<tr>
<td>Tempe, AZ (n = 33)</td>
<td>60.95 ± 5.50b</td>
<td>60.09 ± 5.39b</td>
<td>−1.24 ± 0.89</td>
<td>4.10 ± 0.15b</td>
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</tbody>
</table>

**Age**

<table>
<thead>
<tr>
<th>Age</th>
<th>Initial BW</th>
<th>Final BW</th>
<th>% BW Change</th>
<th>Initial BCS</th>
<th>Final BCS</th>
<th>BCS change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 yr (n = 22)</td>
<td>36.87 ± 5.04a</td>
<td>36.00 ± 4.83a</td>
<td>−1.02 ± 1.01</td>
<td>3.20 ± 0.08a</td>
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<tr>
<td>2 yr (n = 33)</td>
<td>53.05 ± 4.50bc</td>
<td>51.36 ± 4.38bc</td>
<td>−2.98 ± 0.77</td>
<td>3.39 ± 0.09abc</td>
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<tr>
<td>3 yr (n = 30)</td>
<td>52.48 ± 6.54abc</td>
<td>51.36 ± 6.22abc</td>
<td>−1.50 ± 0.99</td>
<td>4.00 ± 0.14cd</td>
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<tr>
<td>4 yr (n = 22)</td>
<td>67.45 ± 6.50c</td>
<td>65.95 ± 6.20c</td>
<td>−1.87 ± 0.99</td>
<td>3.73 ± 0.10bcd</td>
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<tr>
<td>5 yr (n = 25)</td>
<td>59.82 ± 5.83bc</td>
<td>58.93 ± 5.74bc</td>
<td>−0.99 ± 1.20</td>
<td>3.92 ± 0.18cde</td>
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<tr>
<td>6 yr (n = 29)</td>
<td>52.09 ± 4.46abc</td>
<td>51.35 ± 4.42bc</td>
<td>−1.28 ± 0.79</td>
<td>3.84 ± 0.14cde</td>
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<tr>
<td>7 yr (n = 11)</td>
<td>43.62 ± 8.47abc</td>
<td>42.39 ± 8.16ab</td>
<td>−2.18 ± 1.98</td>
<td>3.50 ± 0.15abc</td>
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</tr>
</tbody>
</table>

**Size**

<table>
<thead>
<tr>
<th>Size</th>
<th>Initial BW</th>
<th>Final BW</th>
<th>% BW Change</th>
<th>Initial BCS</th>
<th>Final BCS</th>
<th>BCS change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toy (n = 16)</td>
<td>9.37 ± 0.85</td>
<td>9.45 ± 0.84</td>
<td>1.14 ± 0.94</td>
<td>3.12 ± 0.08a</td>
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<tr>
<td>Small (n = 31)</td>
<td>21.67 ± 0.67</td>
<td>21.59 ± 0.65</td>
<td>−0.18 ± 0.85</td>
<td>3.53 ± 0.12b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium (n = 33)</td>
<td>39.78 ± 1.17</td>
<td>38.66 ± 1.02</td>
<td>−2.31 ± 1.13</td>
<td>3.52 ± 0.10b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium to large (n = 35)</td>
<td>59.14 ± 0.89</td>
<td>58.05 ± 0.97</td>
<td>−1.97 ± 0.89</td>
<td>3.50 ± 0.11b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large (n = 22)</td>
<td>71.94 ± 0.66</td>
<td>70.23 ± 0.79</td>
<td>−2.32 ± 0.96</td>
<td>3.82 ± 0.14b</td>
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</tr>
<tr>
<td>Very large (n = 20)</td>
<td>82.78 ± 0.88</td>
<td>81.44 ± 1.07</td>
<td>−1.62 ± 0.76</td>
<td>4.32 ± 0.16c</td>
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</tr>
<tr>
<td>Giant (n = 16)</td>
<td>106.65 ± 3.96</td>
<td>103.05 ± 3.45</td>
<td>−3.60 ± 1.11</td>
<td>4.22 ± 0.15c</td>
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<td></td>
</tr>
</tbody>
</table>

Means in a column (within Feeding Practice, Location, Age, or Size) with different superscript letters differ significantly (P < .05).

*Group 1 = dog food only; Group 2 = dog food + biscuits/treats; Group 3 = dog food + human foods; Group 4 = dog food + biscuits/treats and human foods.

†Data missing for one dog.
started, and 100 dogs (57.80%) lost weight. Dogs that gained weight had a mean increase in weight of 3.57% ± 0.369%, with a range of 0.12% to 13.10%. Dogs that lost weight had a mean decrease in weight of –4.84% ± 0.333% with a range of –0.12% to –14.44%. The dogs that either maintained or gained weight during the study had a mean initial BCS of 3.53/5 and a mean final BCS of 3.48/5. Dogs that lost weight began the study with a mean BCS of 3.79/5 and finished the study with a mean BCS of 3.51/5.

No significant differences in initial and final BW, percent change in BW, final BCS, or change in BCS were observed among dogs in the different feeding practices groups (Table 3). Dogs in Group 1 tended ($P = .10$) to lose slightly more weight than dogs in the other groups. These dogs also had significantly ($P < .05$) higher BCS values at the start of the study compared with dogs in Group 4 (Table 3) and tended ($P = .07$) to have a higher final BCS.

No significant effects of the subject’s location (city) were found for changes in BW or BCS over the 10-week period. However, mean BW (initial and final) of dogs living in Houston was significantly ($P < .05$) lower when compared with mean BW of dogs in the other locations. Likewise, initial and final BCS scores of dogs living in Tempe were significantly ($P < .05$) higher than mean BCSs of dogs in the other four cities.

A significant age effect was found for initial and final BW and BCS ($P < .05$), with 1-year-old dogs having the lowest and 4-year-old dogs having the highest mean weights before and after the study. There was no age effect observed on change in weight over the 10-week study period ($P = .57$), although 2-year-old dogs tended to lose more weight than dogs younger or older than them while 3-year-olds were most likely to maintain BW. Dogs 2 years of age or younger had significantly lower mean initial and final BCSs compared with older dogs. Three-years-old dogs had the highest initial and final BCS.

While percent change in BW did not differ significantly among dogs in the seven size categories, initial and final BCS and change in BCS did. Small dogs had a lower BCS (initial and final) compared with large dogs. Toy dogs had significantly lower initial BCS values compared with all other size categories (mean = 3.12/5; $P < .05$). Dogs categorized as very large and giant had the highest initial BCS (mean = 4.32 and 4.22/5, respectively; Table 3). Final BCS
showed a similar pattern with size category, with the exception of giant dogs showing a decrease in BCS to 3.62/5. Change in BCS over the 10-week period was significantly greater for dogs classified as giant compared with all of the other six groups of dogs (Table 3). No differences in BCS change were observed between any other size categories.

**Activity Constant Estimates**

Regression analysis of total daily caloric intake as a function of metabolic BW ($BW_{kg}^{0.67}$) for the entire group of dogs ($n = 173$) produced an activity constant ($K$) of 106.61 ($P < .05$, $R^2 = .95$), and a range of $K$ values of 78.5 – 142.7 (Table 4, Figure 3). An activity constant for adult maintenance was estimated using dogs that maintained ±1.5% of initial BW over the 10-week period ($n = 40$). The difference between initial and final BW for this group of dogs was not significant, as determined by a paired $t$-test ($P = .639$). Regression analysis produced an activity constant of 103.29 for this group of dogs ($P < .05$, $R^2 = .96$), with a range of values between 78.5 and 139.8 (Figure 4). When a value of ±2.0% change in BW was used ($n = 55$), differences between initial and final BW were not significant ($P = .06$) and a $K$ value of 104.37 ($P < .05$, $R^2 = .95$) was produced with the same range of individual values.

Regression analysis was also conducted using an exponent of 0.75 for conversion of BW to metabolic BW. When $BW_{kg}^{0.75}$ was used, a $K$ value of 74.49 was calculated for the entire group ($P < .05$, $R^2 = .95$; data not shown). The range of $K$ values was 65.1 to 119.6. Similar $K$ values were produced for the dogs that maintained weight.

Power regression analysis was conducted by plotting total intake (kcal/day) against mean BW (kg) to determine a best-fit exponent for converting dogs’ BW to metabolic BW. When all of the dogs in the study were included in this analysis, an exponent of 0.66 provided the best estimate of metabolic BW ($P < .05$, $R^2 = .96$; data not shown). When the group of dogs that maintained ±1.5% of initial BW was used to determine the exponent ($n = 40$), a value of 0.64 was calculated ($P < 0.05$, $R^2 = .96$; Figure 5).

A significant linear relationship was seen between age and $K$ value ($P < .05$), with higher $K$ values noted in younger dogs (Table 5). Dogs that were 1 and 2 years of age had significantly higher $K$ values than those between 3 and 7 years of age. A linear relationship between $K$ value and size was not seen, but dogs in the toy

<table>
<thead>
<tr>
<th>Group</th>
<th>$n$</th>
<th>Mean Initial BW (lb)</th>
<th>Mean Final BW (lb)</th>
<th>$\Delta$ in % BW$^b$</th>
<th>Estimated K ($BW_{kg}^{0.67}$)</th>
<th>K value Range ($BW_{kg}^{0.67}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All dogs</td>
<td>173</td>
<td>52.88</td>
<td>51.75</td>
<td>S ($P &lt; .05$)</td>
<td>106.61</td>
<td>78.5–142.7</td>
</tr>
<tr>
<td>Maintainers (±2.0% BW)</td>
<td>55</td>
<td>54.72</td>
<td>54.52</td>
<td>NS ($P = .06$)</td>
<td>104.36</td>
<td>78.5–139.8</td>
</tr>
<tr>
<td>Maintainers (±1.5% BW)</td>
<td>40</td>
<td>49.43</td>
<td>49.39</td>
<td>NS ($P = .64$)</td>
<td>103.29</td>
<td>78.5–139.8</td>
</tr>
</tbody>
</table>

$S =$ significant; NS = not significant.

$^a$All regression R-square values were $\geq .95$; $P < .05$.

$^b$Change in body weight (BW) tested using a paired $t$-test (initial vs. final BW).
category tended to have higher \( K \) values (Table 6).

## DISCUSSION

An objective of the study reported here was to collect data from owners of typical American dogs, living as companions in homes, that were fed an adult maintenance diet in accordance with the feeding guidelines on the bag. Dogs were selected through a standard, random telephone survey that was designed to identify healthy adult dogs between 1 and 7 years of age, living in single-dog homes. Dogs described by their owners as being highly active or found to be underweight (BCS \( \leq 2.5/5 \)) at the first weigh-in period were not selected for the study. Highly active dogs often require a diet that is more nutrient and calorie dense than a typical adult maintenance food and so would not be representative of the target population. Similarly, underweight dogs may have been unhealthy or receiving an inappropriate diet for their activity level. Moreover, given that up to 40% of dogs living in American households are currently overweight or obese and that underweight conditions in these animals are uncommon, dogs with low BCSs were not considered to be within the target population for the study design. Dogs from multiple-dog homes were not included in the present study because the study design required owners to precisely record and measure their pet's daily dog food allotment along with all treats and human foods that were fed. While the authors recognize that examining feeding patterns in multiple-dog households is of interest for future studies, only single-dog homes were included in the present study to minimize recording error and promote client compliance.

Other studies surveying feeding patterns of pets in homes have selected dogs either through veterinary clinic client lists or through a pet insurance database.\(^{19,20}\) Veterinary clinic selection may include some dogs that are ill or injured, while selection through a pet insurance database may include a disproportionate number of strongly committed owners from higher socioeconomic classes. Selection through random telephone surveys has the advantage of identifying a subpopulation that is representative of the overall pet-owning public and is also suitable for surveying different geographic areas. In the present study, a wide range of breeds and sizes of dogs were selected from five different cities within the continental United States.

The majority of dogs (66.5%) included in

\[
\text{ME (kcal/day)} = 106.61 \times (\text{BW}_{kg}^{0.67})
\]

Figure 3. Caloric intake (mean kcal/day) vs. metabolic body weight (\( \text{BW}_{kg}^{0.67} \)) in all dogs (\( n = 173 \)).
this study were purebred, with Labrador and golden retrievers the two most common breeds (n = 19 and 16, respectively). This proportion is consistent with recent survey data collected by the American Pet Products Manufacturing Association (APPMA). Similarly, the dog registration records of the American Kennel Club (AKC) show that Labrador retrievers were the most common AKC breed in the United States in 2001 and golden retrievers were second in registration number. The percentage of dogs in the present study that were neutered (86%) is slightly higher than the proportion reported in other studies of US dogs. There is no apparent explanation for this, except that it may reflect a growing awareness of the benefits of spaying and neutering companion animals. Together, all of these results indicate that the 173 dogs included in this study provide a representative sample of companion dogs living in homes in the United States.

The mean age of dogs in this study (3.73 years) was slightly lower than that reported by APPMA (6.6 years for the first dog in the family and 5.1 years for the second dog). This difference is probably due to the purposeful exclusion of dogs older than 7 years in our study. This was done to ensure that a mature but not elderly sample of dogs was selected. Since current feeding guidelines do not account for age differences between dogs, elderly dogs that may have had reduced energy needs or chronic illness that affect activity levels or energy needs were intentionally excluded. However, because the APPMA data indicate that aging dogs comprise a substantial proportion of American pets today, examining differences in feeding patterns and energy needs of older adult pets in homes is an important area for future study.

Several differences were observed among dogs living in different cities. Dogs living in Houston were generally smaller than dogs living in the other cities, and dogs living in Tempe were more likely to be overweight. There are no explicit explanations for these differences but it is possible that the Houston group of owners represented an urban population, including more apartment dwellers who would tend to keep smaller dogs. The smaller mean size may also reflect a regional preference for a certain type or breed of dog. The higher initial BCS of the Tempe dogs may reflect the age distribution of dogs from that city rather than an actual location effect on BCS value. Also in the Tempe group, only one dog was 1
year of age while the majority (54.5%) were 4 years of age or older. In contrast, in the other four cities the number of 1-year-old dogs ranged from three to nine. Because the young dogs in this study were more likely to be at their ideal body condition than older dogs, the apparent location effect may simply reflect the larger proportion of middle-aged dogs living in Tempe.

The young adult dogs in the study (1 and 2 years of age) had BCSs that were closer to ideal BW (BCS = 3.0 to 3.5/5) compared with dogs that were older. Interestingly, 3-year-old dogs were the heaviest (mean initial BCS = 4.0/5), indicating that dogs that become overweight do so shortly after reaching adulthood. This may reflect a tendency of owners to continue to feed their dogs the same amount of food that they provided during growth. Like other mammals, the energy needs of dogs decrease as they reach adulthood. Some owners may not be aware of this natural decline and continue to provide the same amount of food as their dog matures, leading to obesity in young adult dogs. The early onset of overweight conditions seen in this study is an important consideration for pet food manufacturers developing feeding guidelines and for veterinarians educating clients regarding feeding practices of young dogs.

A dog’s breed may also influence body condition. Certain breeds appear to have a disproportionately high incidence of obesity compared with the general population of dogs. Cocker spaniels, Labrador retrievers, and golden retrievers have all been identified as breeds that are predisposed to overweight conditions. In the present study, 12 of the 19 Labrador retrievers (63%), 11 of the 16 golden retrievers (69%), and five of the seven cocker spaniels (71%) had initial BCSs of 4.0/5 or higher. By comparison, 48.5% of the entire group of 173 dogs had initial BCSs of 4.0/5 or higher at the start of the study. This suggests that the dogs in the present study showed a breed-related susceptibility to being overweight similar to that reported by other authors.

The feeding practices of owners are often targeted as an important contributor to overweight or obese conditions in dogs. The methodology used in this study required owners to record the amount of commercial dry diet, all treats, and all human foods that their dog consumed daily. Participants were allotted enough commercial food for each 2-week period and were required to return any remaining food to study representatives at each weigh-in

Figure 5. Caloric intake (mean kcal/day) vs. body weight (kg) in dogs maintaining ± 1.5% BW (n = 40).
TABLE 5. Effect of Age on Activity Constant (K)

<table>
<thead>
<tr>
<th>Age Category</th>
<th>K value (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 yr (n = 22)</td>
<td>111.07 ± 2.09&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2 yr (n = 33)</td>
<td>109.32 ± 2.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3 yr (n = 29)</td>
<td>106.00 ± 2.13&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>4 yr (n = 22)</td>
<td>105.23 ± 2.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>5 yr (n = 25)</td>
<td>105.55 ± 1.68&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6 yr (n = 29)</td>
<td>105.22 ± 1.16&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>7 yr (n = 11)</td>
<td>105.37 ± 2.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means in a column with different superscript letters differ significantly (P < .05).

TABLE 6. Effect of Size Category on Activity Constant (K)

<table>
<thead>
<tr>
<th>Size Category</th>
<th>K value (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toy (n = 16)</td>
<td>111.38 ± 3.87</td>
</tr>
<tr>
<td>Small (n = 31)</td>
<td>105.00 ± 2.46</td>
</tr>
<tr>
<td>Medium (n = 33)</td>
<td>106.74 ± 1.25</td>
</tr>
<tr>
<td>Medium to large (n = 35)</td>
<td>107.52 ± 1.58</td>
</tr>
<tr>
<td>Large (n = 22)</td>
<td>106.42 ± 1.79</td>
</tr>
<tr>
<td>Very large (n = 20)</td>
<td>104.85 ± 1.37</td>
</tr>
<tr>
<td>Giant (n = 16)</td>
<td>108.26 ± 1.97</td>
</tr>
</tbody>
</table>

P = .51

period. Food allotments were based on biweekly weights to maintain consistency with the first objective of the study. When food allotment changes occurred, they were typically no greater than 1/4 cup per day.

Obtaining accurate and repeatable food intake data is important. To minimize error, methods employed by human intake studies were utilized. Similar studies in humans commonly validate written records either by comparing records with periods of weighed food intake or by measuring the repeatability of recorded intake data. Similar approaches have been used to previously validate food intake records in dogs. These have reportedly good to excellent repeatability for energy intake and food itemization of frequently fed foods. In our study, intake records were reviewed every 2 weeks by study representatives, instructions for completing the daily records were reiterated, and noncompliant owners were dropped from the study. Although weighing food or including an observer at feeding times may have provided additional data, these approaches are not practical in most home settings and could result in changes in feeding habits. The use of daily food records has been validated by other authors and appears to provide an accurate estimate of the foods and calories that are consumed by dogs in homes without introducing study bias.

Most dog owners in the United States and other countries are in the habit of regularly providing dog treats and human foods to their pets. The daily food diaries collected in this study showed that the majority of owners (78.0%) fed dog treats and/or human foods to their dogs. A wide variety of biscuits was fed, ranging from generic or locally marketed private label brands to premium treats sold only through pet store outlets. Similarly, a very wide variety of human foods was offered to dogs. The human foods that were most frequently reported included hot dogs, meat and meat scraps (most commonly chicken meat or chicken breast), cheese, and bread slices. These results are in agreement with other studies reporting that owners tend to feed a high proportion of table scraps consisting of some type of meat, with chicken particularly popular. Because feeding special treats to animal companions is one way in which owners ex-
press affection and love, it follows that the most popular types of foods that are offered are those that dogs relish, such as foods that are high in both fat and protein.

It is commonly believed that dogs that are fed extra biscuits or human foods consume more calories and are at greater risk of obesity than dogs of similar size that are not fed any extra treats. When the feeding practices of owners of normal-weight dogs were compared with feeding practices of owners of obese dogs, no differences were found in the types of commercial foods fed but owners of obese dogs were more likely to feed treats and table scraps than were owners of normal-weight dogs. Conversely, a study of 339 dog-owning households reported that the provision of snacks and treats was not significantly correlated with the occurrence of obesity in dogs. In the present study, dogs fed additional treats or human foods did not consume more total calories per day than dogs fed only commercial dog food, nor were they more likely to be overweight. However, dogs fed only their dry diet did tend to have slightly higher mean intake of calories from their dry food compared with groups of dogs fed extra treats or human foods. These data indicate that dogs that are fed dog biscuits and human foods may be less likely to consume all of the dry diet that is offered and make up the difference in calories with the extra treats and human foods provided by their owners. This finding suggests that providing extra treats replaces some of a dog’s dry diet but does not necessarily supplement the diet with additional calories. Dogs that are offered highly palatable human foods or dog treats may simply eat less of the maintenance pet food that is offered. Thus, the notion that offering a pet too many palatable table scraps may produce a “finicky eater” is supported by these results.

Although no differences were observed in total calories consumed per day among feeding practice groups, the body condition of dogs in different feeding practice groups did differ significantly. Dogs that were fed only their dry food each day were more overweight and tended to lose more weight than dogs fed human foods and dog treats. This group of dogs also had final BCS values that were still higher than ideal. This trend may relate to owners’ perceptions of their dog’s body condition at the start of the study. The tendency of owners of the overweight dogs to feed only the prescribed dry diet during the 10-week study may reflect a conscious (or subconscious) effort to modify their feeding practices while enrolled in the study in response to learning at the initial BCS assessment that their pet was overweight.

The daily food records collected in this study provided data for the determination of MER equations for pet dogs living in homes. Calculating a single MER equation and developing feeding guidelines that apply to all dogs are complex tasks because of the wide variations in pet dogs’ size, body conformation, activity level, and age. Differences in BW can be addressed through the use of an allometric equation that converts BW to metabolic BW by raising mass to a predesignated power. The exponent that is used for this conversion has historically been calculated using data collected from a wide range of species. Initial work with different mammalian species suggested an exponent of 0.73, but this value was subsequently increased to 0.75. However, the appropriateness of 0.75 for intraspecies conversion has been questioned and lower estimates have been suggested for determining metabolic BW within species and specifically for the domestic dog. In the study reported here, the best-fit estimate for a mass exponent to convert BW to metabolic BW for adult dogs at maintenance was determined to be 0.64 (Figure 3). Data used to generate this value included dogs ranging in BW from 5 to over 100 lb,
with a mean BW of 49.43 lb. All of the dogs were adults within their prime years, with no elderly dogs included. Other researchers have suggested that a higher exponent (0.75 or greater) may be optimal for some giant breeds, such as Great Danes, while an exponent between 0.64 and 0.70 may be more appropriate for most adult dogs. In the present study, an exponent of 0.67 was used to determine metabolic BW and to calculate the amount to feed each dog. This value closely approximates the best-fit exponent determined through regression analysis of the dogs that maintained BW over a 10-week period (i.e., 0.64). Because these dogs represent a relatively wide range of sizes and breeds, a mass exponent of 0.67 for the conversion of BW to metabolic BW appears to be a suitable exponent to use for in-home adult dogs.

In the past, most studies of dogs’ energy requirements have been conducted with either racing dogs or dogs housed in kennels. The energy needs of racing sled dogs and greyhounds are substantially higher than the needs of dogs at maintenance and for this reason do not provide an accurate estimate for most house dogs. Kennel dog studies may also significantly overestimate the maintenance needs of companion dogs. There is recent evidence that the overall activity level of kennel dogs housed in thermoneutral environments is substantially greater than that of dogs of similar size and age that live in homes. This may occur because kennel dogs are typically housed with a large number of other dogs, experience periodic episodes of great excitement and activity, and may be subject to stresses that are associated with the kennel environment. Comparatively, most house dogs experience relatively stable daily routines and low to moderate levels of exercise. Therefore, energy requirement equations and feeding guidelines that are derived from studies of dogs in kennels are expected to overestimate the energy needs of most pet dogs living in homes. Several other studies have examined energy needs of pet dogs living in homes. When the energy needs of working border collies were compared with those of pet border collies, food intake survey data showed a wide range of energy needs. Pet border collies had the lowest mean MER, and the increased activity in the working dogs resulted in an almost twofold increase in MER. However, this study included only 47 dogs, all of which belonged to a single breed. Other in-home studies have included multiple breeds but evaluated only a small number of dogs (n = 14 to 48). Additionally, all of the dogs in these three studies were owned by individuals who were associated with the research team in some way or were selected retrospectively through the authors’ nutrition consultation service. No other published studies have measured energy needs of healthy dogs living in typical pet homes from varied geographic regions within the United States, nor have any other studies reported data on a large number of dogs representing a wide size range as well as different breeds and breed mixes. Because the methodology used in the present study provided information about typical adult dogs living in homes around the continental United States, the energy intake data and resultant activity constants that were generated may more closely approximate the true needs of pet dogs than previous studies. Similar to earlier in-home studies, a subset of pet dogs that maintained weight over the study period was used to determine an allometric equation to predict MER. In this study, regression analysis was used to calculate a best-fit line for MER in a subset of 40 dogs that maintained BW (±1.5%) over the 10-week study period. These dogs ranged in size from 5 to 114 lb. Regression analysis produced the following equation: MER =
103.29(BW kg)0.67. When all 173 dogs were included in the equation, the K value was only slightly higher (106.61), even though mean weight of this group declined very slightly. In addition, the range of K values for individual dogs was almost identical to that of the smaller subset of dogs.

Although an allometric equation for predicting MER is helpful in providing a starting point for estimating energy needs, its use for determining an exact energy requirement of an individual animal is limited. Dogs in this study had a range of calculated K values between 78.5 and 142.7. The inherent variability in the population of pet dogs in terms of energy requirements is further illustrated by the wide range in BW and intake responses to the feeding protocol. Over the 10-week period, 73 dogs either maintained their initial BW (10 dogs) or gained weight (63 dogs), while 100 dogs lost weight. In addition, daily food records showed that one-third (57 dogs) did not consume all of their daily allotment of dog food at various times during the study period.

The wide range of K values observed in these dogs may be explained by recognizing that using energy balance and maintenance of BW to calculate an activity constant includes multiple factors that influence an individual dog’s MER. In addition to activity level, these factors include age, breed, size, and body conformation. While not all of these factors are additive or quantifiable, there is evidence that attributes other than activity, such as age and size, influence a dog’s MER. Because of the limitations of a single allometric equation based on adult dog size, the best possible function for such an equation may be as a starting point for a range of energy values that will include most dogs. In terms of its utility for commercial dog food feeding guidelines, an allometric equation that provides a reasonable starting point that neither severely underestimates nor overestimates energy needs for most dogs living in homes is desirable. The range of 78 to 140 for K values found in the in-home dogs in this study and the resultant K values provided through regression analysis of dogs that maintained weight provide such estimates.

Results of the present study showing that age influences MER are in agreement with results of others. In a study of kennel dogs, the MER of growing dogs was found to be higher than that of young adults between the ages of 3 and 7 years and values were lowest for dogs between 7 and 12 years of age. The present study also indicates that age divisions in MER occur, with young adult dogs (between 1 and 2 years of age) having higher energy needs than adults in their prime years (3 to 7 years of age). After the age of 3, activity coefficients showed no further increase. Because older dogs (>7 years) were not included in this study, it is an intriguing question to further determine if a second decline in energy needs occurs as dogs enter their senior years. Although size category did not consistently affect MER in the present study, the K values for toy dogs tended to be higher than those for medium and large dogs. A dog’s breed may also affect MER. Newfoundlands reportedly have lower energy requirements than adult Great Danes of similar weight. These differences may reflect variation in proportions of lean body tissue in the two breeds. The small number of dogs representing different breeds in the study reported here precludes an examination of breed as a factor but suggest the need for further research studying breed differences in MER.

CONCLUSION

Overall, the results of this study suggest that the determination of an allometric equation describing MER and the development of feeding guidelines from an equation are complex tasks given the number of factors that influ-
ence each dog’s MER. Specifically, relevant differences in age, size, and perhaps breed require further study. These results also suggest that the MER of typical dogs living as companions in homes is generally lower than the published MER values determined from dogs living in kennels and that owner feeding practices must be accounted for when examining energy intake in companion dogs.

A large proportion of dogs in the United States are overweight. Owners’ feeding practices, the use of unrealistic feeding guidelines that overestimate the needs of many dogs, and perhaps skewed owner perceptions of dogs’ body condition may all contribute to this health problem. Therefore, providing feeding guidelines on commercial pet food bags that closely approximate the actual energy needs for most household dogs is warranted. The inclusion of a range of feeding volumes around a realistic starting point for different size categories allows owners to more accurately estimate the needs of their dogs and would prevent owners from initially feeding a level of food that is likely to contribute to overweight conditions. Using in-home feeding studies to determine the needs of pet dogs can also provide an appropriate methodology for identifying subpopulations of dogs whose MER values vary due to differences in age, breed, activity, or body condition and to more precisely define energy requirements of these groups.

**ACKNOWLEDGMENTS**

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**REFERENCES**


