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Metabolisable energy intake and growth of privately owned growing dogs in comparison with official recommendations on the growth curve and energy supply

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The correct assumption of metabolisable energy (ME) requirement is essential for the nutrition consultation and diet formulation. In young dogs, too high energy supply can accelerate growth and thus lead to developmental orthopaedic diseases. The aim of the present study was to collect the data on ME intake and body weight (BW) development in privately owned growing dogs in order to compare these data with the current recommendations. Our hypothesis was that the actual ME intake of healthy young dogs would be lower than the actual recommendation. The data of 493 privately owned puppies (median age at first consultation 21 weeks, the median expected mature BW 30 kg) on ME intake, actual and expected mature BW were collected and compared with recommendations of the Society of Nutrition Physiology (GfE, Meyer and Zentek and NRC). In 243 dogs, there was a follow-up. The actual BW did not deviate systematically from the calculated expected BW (R^2 = .929). The ME intake significantly decreased with age (p < .05) and significantly increased with expected mature BW (p < .05). There was no significant interaction between these two parameters (p > .05). Sex had no effect on the ME intake (p > .05). The ME intake of young dogs with a history of skeletal problems or of food allergy did not differ systematically from healthy dogs of similar age and expected mature BW. The ME intake was considerably below NRC recommendations, especially in younger puppies (>8–17 weeks: 78%, >17–26 weeks: 83% of NRC recommendation). A predictive linear equation for ME intake was developed: ME intake (MJ) = (1.063 − 0.565 × [actual BW/expected mature BW]) × actual $BW^{0.75}$.

KEYWORDS
dogs, energy intake, energy requirement, growth curves, puppy, young growing dogs

1 | INTRODUCTION

Data on metabolisable energy (ME) requirements of pet dogs are a highly important pre-condition for a veterinary nutrition consultation. The same is true for correct instructions for use in pet food manufacturing. In the past, it has been demonstrated that adult dogs kept as pet have lower ME requirements than adult laboratory dogs (Thes et al., 2016). For growing dogs, ME requirements have been assessed by the National Research Council (NRC) (2006) with regard to actual body weight (BW) and expected mature BW. Dobenecker, Endres, and Kienzle (2013) measured the energy intake of laboratory medium-sized and large breed puppies growing according to recommendations

(Society of Nutrition Physiology (GfE) 1989; Meyer & Zentek, 1992; NRC, 2006), and reported a ME intake which was considerably lower than NRC (2006) recommendations during the main growing period. It has been demonstrated repeatedly that a high energy intake in puppies leads to faster growth. This may harm the skeletal development (Dobenecker, Kienzle, Köstlin, & Matis, 1998; Hedhammar, Wu, & Krook, 1974) but does not necessarily cause increased Body Condition Scores (Dobenecker, 2010). Therefore, it is very important that feeding recommendations for growing dogs are close to their ME requirements. In the present study, we collected data on the ME intake, actual BW in relation to the expected mature BW and growth of privately owned growing dogs in order to compare these data with established recommendations.

2 | ANIMALS, MATERIALS AND METHODS

The retrospective study used data from our nutrition consultation service (Chair of Animal Nutrition and Dietetics, Oberschleissheim) gathered between 2007 and 2017. The owners of the young dogs requested a check of the present ration for nutritional adequacy. Owners contacted our nutrition consultation service by phone, fax or e-mail, and then filled out a standardised questionnaire as described previously (Thes et al., 2016). General information data, such as breed, age, actual BW, expected mature BW and case history, if appropriate were collected for each case. The expected mature BW was estimated by the BW of the parent of the same sex as the growing dog, which was asked for in the questionnaire. In case of missing information on the parent BW, data were taken from breed standards (Krämer, 2002). The questionnaire asked about the type and amount of feeds, including special questions in different wordings on supplements and treats. The amount of all feed items and the BW of the dogs were determined by the owners. After the questionnaire was filled out, a follow-up call clarified open questions. The clients received a written report with results of the actual ration (i.e. data on energy and nutrient supply) and BW evaluation, as well as a balanced ration adjustment if necessary. The actual BW of young dogs older than 8 weeks (i.e. past the sigmoid part of the growth curve according to Baumbach, 1999; Kaiser, 2003; Marqua, 2009; Riedel, 2008; Schubert, 2010; Spennes, 2009) was compared with the expected BW calculated with log-curves as given in Table 1. The log-curves are based on recommendations of the GfE (1989) and Meyer and Zentek (1992). GfE (1989) data on a variety of breeds were originally based on Sierts-Roth (1953). In addition, the BW was compared with the WALTHAM growth charts (Salt et al., 2017).

The recommendation for the ME intake was calculated according to the NRC (2006): ME (MJ) = 0.544 × actual $BW^{0.75}$ × 3.2 × ($e^{(-0.87 \times (\text{actual BW/expected mature BW}))}$ − 0.1) and adapted according to growth and reported the previous ME intake. A puppy growing according to the growth curves and consuming 80% of the recommended ME intake according to the NRC (2006) would accordingly get a recommendation of the same ME intake, whereas a puppy growing slower or faster, or being fed less or more would get a recommendation of approximately 5%–10% more or less ME than before respectively. In addition, it was recommended to adjust the ration several times during the growth period to meet the changing requirements. In case of owners complying with this request, the ME intake and growth in the period between consultations were known and evaluated. As

TABLE 1 Equations for growth curves modified after GfE (1989) and Meyer and Zentek (1992), valid from weaning age (8 weeks) to 1 year

Expected mature BW (kg)	Growth curve
≤7	% of expected mature BW = 36.92Ln(age in weeks) − 43.57
>7–15	% of expected mature BW = 36.86Ln(age in weeks) − 48.22
>15–27.5	% of expected mature BW = 39.88Ln(age in weeks) − 60.70
>27.5–47.5	% of expected mature BW = 36.96Ln(age in weeks) − 56.18
>47.5	% of expected mature BW = 36.61Ln(age in weeks) − 62.39

Abbreviation: BW, body weight.

TABLE 2 Breed distribution (% of study population, total *n* = 493)

Breed group	% (*n*)
Sheepdogs and Cattle dogs	14 (71)
Pinscher and Schnauzer	3 (13)
Molosser and Mastiffs	22 (108)
Swiss Mountain dogs	6 (27)
Terriers	3 (16)
Spitz and primitive types	2 (12)
Scent hounds and related breeds	6 (31)
Pointing dogs	3 (17)
Retrievers-Flushing dogs-Water dogs	21 (101)
Companion and Toy dogs	6 (30)
Sighthounds	3 (15)
Mongrels	10 (48)
Other breeds	1 (4)

TABLE 3 Case history of the puppies evaluated in the study (% of study population, total *n* = 493)

Case history	% (*n*)
Healthy	59 (293)
Skeletal diseases	20 (101)
Allergy	12 (57)
Kidney diseases	2 (10)
Urolithiasis	2 (10)
Gastrointestinal diseases	2 (9)
Other	3 (13)

TABLE 4 ME intake of all puppies at first presentation (n = 393), grouped according to age and expected mature BW

Expected mature BW	<15 kg[A]	≥15–27.5 kg[A]	≥27.5–47.5 kg[AB]	≥47.5 kg[B]
Age	MJ ME/kg $BW^{0.75}$ mean ± SD (n)			
8–17 weeks[a]	0.82 ± 0.23 (12)	0.83 ± 0.24 (32)	0.89 ± 0.23 (48)	0.94 ± 0.16 (25)
>17–26 weeks[b]	0.63 ± 0.12 (17)	0.71 ± 0.18 (27)	0.77 ± 0.20 (56)	0.80 ± 0.18 (27)
>26–51 weeks[c]	0.58 ± 0.22 (10)	0.57 ± 0.19 (39)	0.60 ± 0.14 (62)	0.70 ± 0.15 (38)

Note: Age/expected mature BW groups not sharing a superscript letter differ significantly (p < .05).
Abbreviation: BW, body weight; ME, metabolisable energy.

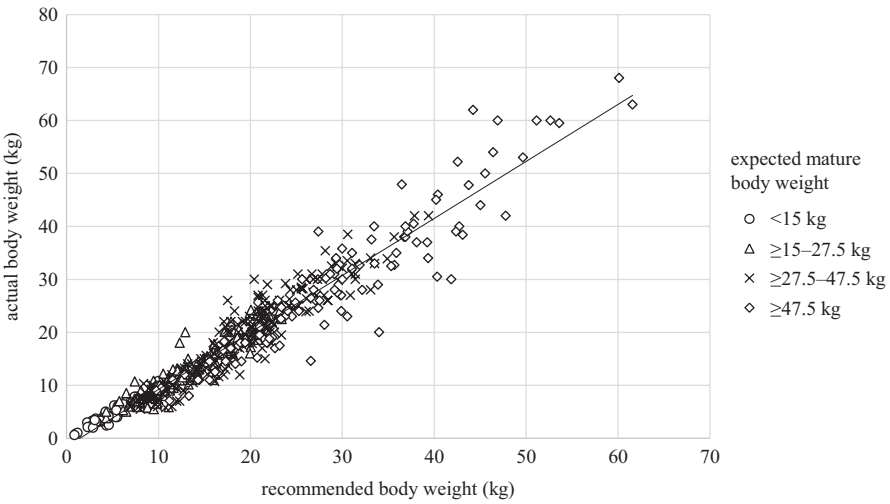

FIGURE 1 Relationship between recommended body weight (BW) (x; kg) and actual BW (y; kg) at the time of first presentation: $y = 1.077x - 1.549$, $R^2 = .929$, $n = 493$

shown in Table 4, the young dogs were grouped according to the expected mature BW and three age groups: >8–17 weeks, >17–26 weeks and >26–51 weeks.

Data on 493 dogs were available. In total, there were 261 male and 232 female young dogs. There were 101 different breeds (Table 2). The majority of the dogs were healthy (Table 3). The median age at first consultation was 21 weeks (range 8–51 weeks). The median expected mature weight was 30 kg (range 1.4–90 kg, Chihuahua and Great Dane respectively). In 243 young dogs, one or more follow-ups took place.

Statistical analyses were performed using the software SigmaPlot 12.5™. Two groups were compared using the Student's t test. To compare more than two groups, one-, two- or three-way ANOVA was performed. A Holm–Sidak test was used as the post hoc test. Linear regressions were calculated between several parameters. Values of P < .05 were considered significant.

3 | RESULTS

The actual BW of the growing dogs did not deviate systematically from the expected BW calculated using the equations from Table 1 (Figure 1). The same was true for those young dogs which were presented a second or third time for adaptation of the ration. In 128 individuals, the actual mature BW was available, that is, they were weighed when adult. On an average, it amounted to 95% of the expected mature weight. When compared to the WALTHAM growth charts (Salt et al., 2017), there was no puppy or young dog showing abnormal growth.

The ME intake of all individuals at the first presentation to the nutrition consultation service grouped according to the age and expected mature BW is shown in Table 4. The ME intake significantly decreased with age (p < .05) and significantly increased with expected mature BW (p < .05). There was no significant interaction in a two-way ANOVA

TABLE 5 Recommendation for the ME intake at first presentation of puppies with further consultations (n = 243)

Expected mature BW	<15 kg[A]	≥15–27.5 kg[A]	≥27.5–47.5 kg[A]	≥47.5 kg[A]
Age	MJ ME/kg $BW^{0.75}$ mean ± SD (n)			
8–17 weeks[a]	0.82 ± 0.18 (14)	0.86 ± 0.16 (26)	0.95 ± 0.16 (52)	0.96 ± 0.15 (21)
>17–26 weeks[b]	0.72 ± 0.13 (7)	0.72 ± 0.13 (16)	0.78 ± 0.18 (38)	0.73 ± 0.12 (16)
>26–51 weeks[c]	0.60 ± 0.02 (2)	0.56 ± 0.14 (11)	0.55 ± 0.10 (26)	0.62 ± 0.12 (14)

Note: Age/expected mature BW groups not sharing a superscript letter differ significantly (p < .05).
Abbreviation: BW, body weight; ME, metabolisable energy.

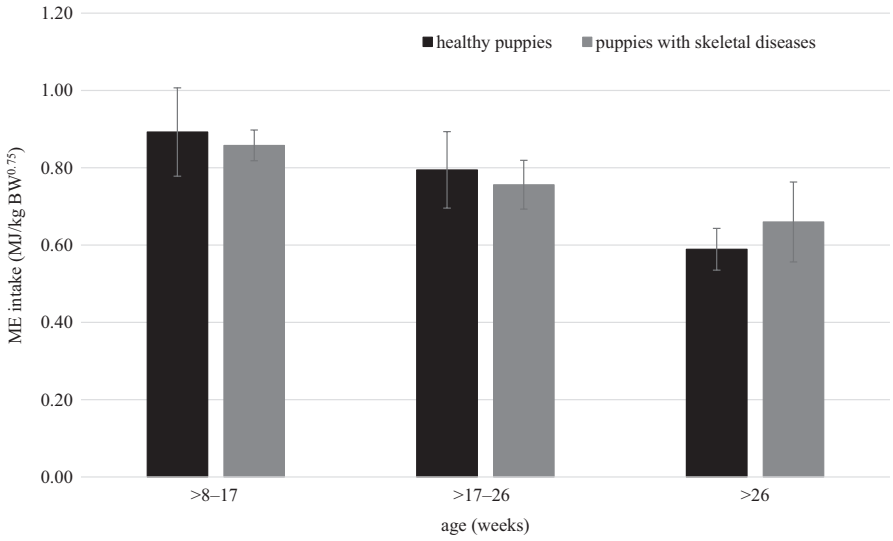

FIGURE 2 Metabolisable energy (ME) intake of puppies with an expected mature body weight (BW) of ≥27.5–47.5 kg, with and without skeletal diseases

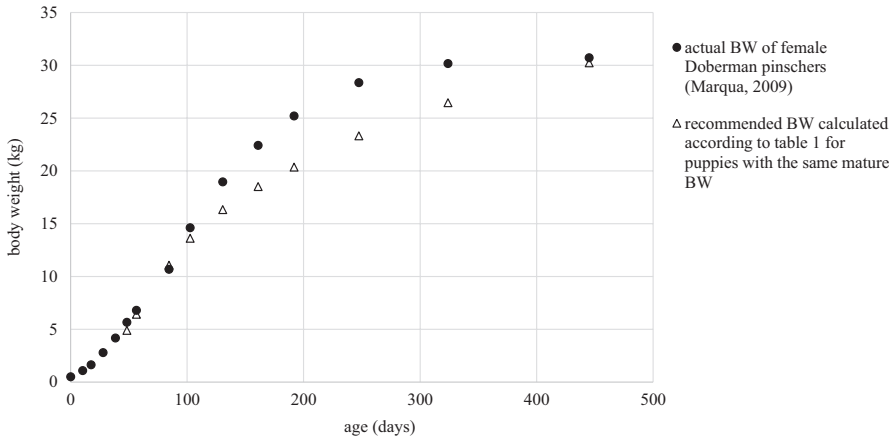

FIGURE 3 Actual body weight (BW) of female Doberman pinschers (Marqua, 2009) compared with recommended BW calculated according to Table 1 for puppies with the same mature BW

between these two parameters ($p > .05$). There was no systematic deviation of our recommendations for the ME intake in the puppies and young dogs with a follow-up consultation (Table 5) and the ME intake of growing dogs at the first consultation (Table 4, $p > .05$). A three-way ANOVA was performed to test the influence of expected mature BW, age and sex on ME intake. Expected mature BW and age had a significant influence on ME intake ($p < .05$) while sex did not have a significant effect ($p > .05$), and there were no interactions between the factors.

There were 101 growing dogs with a history of skeletal problems such as lameness, deviation of limb axes, hip and elbow dysplasia or osteochondrosis dissecans. The actual BW of these dogs did not differ systematically from the expected BW calculated by the equations from Table 1 (Figure S1), though their median expected mature BW amounted to 40 kg compared to 30 kg in the healthy dogs. There was no significant difference in the ME intake between young dogs with skeletal problems and healthy dogs from the same expected mature BW groups and age groups (Figure 2, $p > .05$). The same was true for individuals with a history of food allergy ($p > .05$): There was no significant difference between healthy dogs and dogs with a history of food allergy in all age and weight groups except for an expected mature BW of ≥27.5–47.5 kg at the age of >17–26 weeks. In this group, the four dogs with allergy had a significantly lower ME intake than the 35 healthy ones (0.54 ± 0.29 vs. 0.80 ± 0.20 MJ ME/kg $BW^{0.75}$). The Labrador Retriever represented 12.4 % in the study population. There was no difference in the ME intake between this breed and growing dogs from other breeds ($p > .05$).

4 | DISCUSSION

The most striking finding of this study was the BW, and its development in puppies and young dogs presented in our nutrition consultation service. There was no systematic deviation from the recommendations calculated with log curves from Table 1. Twenty years ago, 57% of young dogs presented to our service were growing too fast according to the same growth recommendations as in the present study (Dobenecker et al., 1998). This suggests that our clients are aware of the risks of overfeeding growing dogs and tried to avoid them. In this context, it should be mentioned that the incidence of obesity in adult dogs is also quite low in our service. However, the demography of our clients does not reflect the general population in Germany. Bergler, Zorn, and Kienzle (2007) observed that our clients have an above-average income and education and a high interest in preventive health care. Back in the 1990s, many cases were

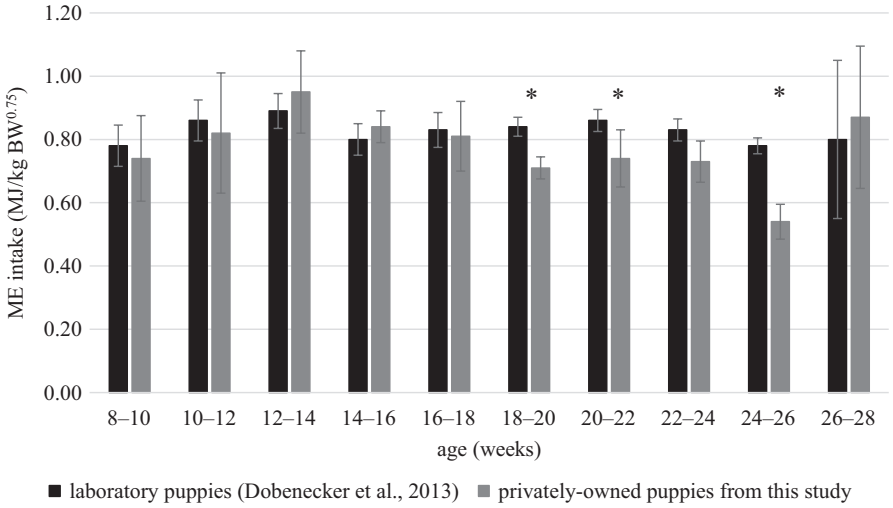

FIGURE 4 Metabolisable energy (ME) intake of privately owned puppies compared with ME intake of laboratory puppies (Dobenecker et al., 2013) from the expected mature BW group ≥15–27.5 kg. The laboratory puppies showed significantly higher ME intakes at the age of 18–22 and 24–26 weeks ($p < .05$)

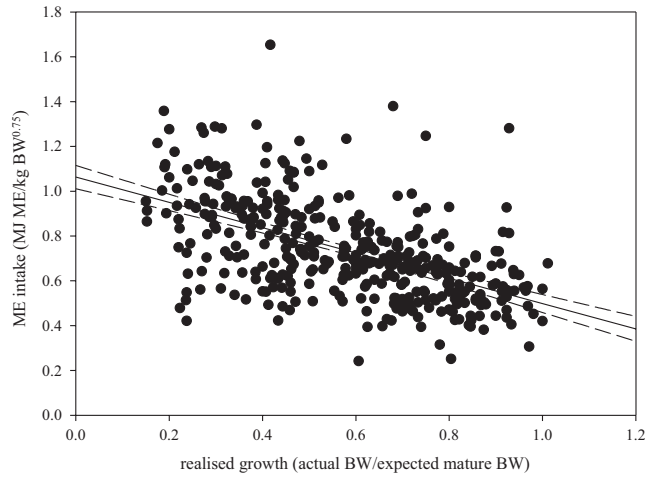

FIGURE 5 Metabolisable energy (ME) intake (y; MJ/kg $BW^{0.75}$) in relation to realised growth (x; actual BW/expected mature BW): $y = -0.565x + 1.063$, $R^2 = .307$, $n = 393$, broken lines mark the 95% confidence interval. BW, body weight

referred from the local clinicians to our nutrition consultation service, while later on, clients with young dogs started to approach us on their own interest in order to prevent nutrition-related growth disorders. Therefore, it is more likely that this finding does not reflect a general shift of feeding in the population of growing dogs in Germany but rather a shift within our clients towards preventive nutrition consultation. It is quite remarkable how closely the growth of the dogs matches the recommended growth curve (first consultation $R^2 = .929$, second consultation $R^2 = .932$, third consultation $R^2 = .921$, regression line close to X=Y). It is unlikely that the clients already used our growth curves given the fact that there is a multitude of growth curves on the internet. The growth curves of GfE (1989) and Meyer and Zentek (1992) used for our nutrition consultation are based on the data obtained in post-World War II Germany from breeders and privately owned puppies and young dogs by Sierts-Roth (1953) plus some experimental data (see GfE, 1989). At the time of data collection by Sierts-Roth, Germany was a comparatively poor society and most people could not afford to overfeed their growing dogs—it even appears likely that only relatively wealthy people were able to afford breeding or keeping dogs for pleasure. In children, it is a well-known fact that unconstrained growth is a privilege of subpopulations with high parental education and household income both in poor as well as in rich societies (Bielicki, 1986; Júlíusson et al., 2010; Ogden, Lamb, Carroll, & Flegal, 2010; Owusu, Lartey, De Onis, Onyango, & Frongillo, 2004; Wang & Zhang, 2006). It is tempting to speculate that the same is true for pet dogs. These hypotheses are strengthened when the growth of dogs from more recent field studies with breeders and privately owned puppies in Germany is compared to our growth curves (Baumbach, 1999; Kaiser, 2003; Marqua, 2009; Riedel, 2008; Schubert, 2010; Spennes, 2009). The majority of the puppies from these studies are heavier than recommended (Figure 3) by the growth curves from Table 1, regardless of breed.

When the growth curves for dogs were developed in 1989 (GfE), logarithmic adaptations were used. The rationale behind this was that the curves were intended for the use mainly after weaning, and at that time point, logarithmic curves give a reasonable fit. In addition, the computer capacity to calculate in a more sophisticated manner growth curves from these unevenly distributed data was not available.

The growth of dogs with repeated consultations from this study was also in agreement with recommendations. We recommend that in underweight or ideal weight puppies the puppies' BW should develop parallel to the corresponding growth curve, in overweight puppies it should develop a bit slower closing up to the growth curve. The excellent agreement between actual BW and recommended BW of the dogs at first and at following consultations suggests that most people manage to keep their dogs grow according to recommendations with the help of correct nutritional advice. The obvious question is whether owners report their young dog's BW correctly. Given the agreement between recommendations at the first consultation and the multitude of differing growth curves on the internet and in the popular literature, it is unlikely that this is just an effect of the misreported data. In addition, the owners had to pay a considerable fee for the consultation which motivates them to give the correct data on BW. The same is true for the nutrition history.

A standardised questionnaire is used with questions formulated in a manner to avoid social desirability effects. Supplements are asked for in different wordings explaining what is meant. In addition, most cases are discussed with the owner on the phone. Data are checked for plausibility, and if there are discrepancies the owners were contacted and asked specifically. These methods of obtaining the data and calculating ME intake have been used repeatedly and led to plausible results in several previous studies (Dillitzer, Becker, & Kienzle, 2011; Thes et al., 2015, 2016), and it is discussed there.

The ME intake of privately owned young dogs agreed with observations of Dobenecker et al. (2013) in laboratory puppies with ideal growth according to the above recommendations up to an age of 18 weeks (Figure 4). In this study (Dobenecker et al., 2013), laboratory puppies showed a significantly higher ME intake at several time points. The ME intake of privately owned young dogs was considerably below NRC (2006) recommendations. A two-way ANOVA testing the influence of age and expected mature BW on ME intake in % of recommendation revealed a significant effect of age group (i.e., overestimate of ME intake according to NRC (2006) requirements was higher in younger puppies) but not of expected mature BW group on ME intake, and no significant interaction of the influencing factors. This again agrees with the results of Dobenecker et al. (2013) on laboratory puppies. NRC (2006) recommendations overestimated especially the ME intake of younger puppies. Dobenecker et al. (2013) hypothesised that this finding was due to a lower maintenance requirement of younger puppies than presumed by the NRC (2006) resulting from a lower activity at this age. This would also explain why there is no difference between pet and laboratory puppies at this age.

For the use in a nutrition consultation and diet formulation the recommendations on ME intake of growing dogs stated by the NRC (2006) should be re-evaluated. In weaned puppies younger than 6 months, the ME intake averages approximately 80% of the NRC (2006) recommendation (>8–17 weeks: 78%, >17–26 weeks: 83% of NRC recommendation), and in older puppies approximately 88% of this recommendation.

Realised growth (actual BW/expected mature BW; *x*-axis) was plotted against the ME intake per kg $BW^{0.75}$ on the *y*-axis (Figure 5). The plot suggests a linear relationship between these parameters. It seems that the net result of the increased activity and thus the higher maintenance requirements and the decrease of requirements for growth is a linear decrease of total ME intake per kg metabolic BW with increasing realised growth. There was no systematic effect of expected mature BW. The ME intake of a dog's growth according to recommendations can thus be estimated by the regression equation $y = -0.565x + 1.063$ (Figure 5). The resulting equation to calculate the absolute ME intake is (MJ) = (1.063 − 0.565 × [actual BW/expected mature BW]) × actual $BW^{0.75}$. It is notable that the individual differences of ME intake are quite high. The same has been observed for laboratory and pet dogs during maintenance (Rainbird & Kienzle, 1989; Thes et al., 2016). For individual ration calculation, this problem can be approached by calculating the ME intake before changing the ration to help to get the right starting point of ME intake. It is a challenge for pet food formulation. A complete compound feed is defined as a feedstuff that provides energy and all nutrients in sufficient quantities without causing deficiency or detrimental excess. Given the huge individual differences in the ME intake in young dogs with similar realised growth, it can be quite challenging to find nutrients/energy ratios that fit for very different energy intakes, especially with nutrients where deficiency and adverse effects are rather close together such as for calcium (NRC, 2006).

In the growing dogs with repeated consultations during the main growth period (i.e., 8–17 weeks of age) we looked at the relationship between ME intake and BW gain per kg $BW^{0.75}$. Dogs with a daily BW gain of 0–10 g/kg $BW^{0.75}$ had a ME intake of 0.77 ± 0.17 MJ/kg $BW^{0.75}$/day. Dogs gaining more weight (i.e., 20–30 g/kg $BW^{0.75}$/day) had a higher ME intake (0.97 ± 0.16 MJ/kg $BW^{0.75}$/day).

5 | CONCLUSION

Standard growth recommendations (GfE, 1989; Meyer & Zentek, 1992; NRC, 2006;) are useful to control the dog's BW development. The recommendations for the ME intake for growth of the NRC (2006) are too high for both laboratory and privately owned growing dogs. The ME intake of privately owned young dogs grown according to recommendations can be calculated by the following equation: ME intake (MJ) = (1.063 − 0.565 × [actual BW/expected mature BW]) × actual $BW^{0.75}$.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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