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Body Surface Area in Young Cattle is Well Correlated with Body Length

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Abstract

Measurements of Body Surface Area (BSA) in animals have important applications in numerous fields including zootechnics, clinical medicine, and also the leather industry. In current conditions, BSA is estimated from formulas that are normally based on body weight (BW). Care must be taken when deciding which equation to use when estimating BSA. Moreover, BW is a trait not easily taken under field conditions. In order to study whether body length (BL), an easy-to-take trait, is well correlated with BSA, 40 animals (20 males and 20 females) aged between 205 and 396 days belonging to typical European meat breeds were studied by means of a capturing-area program. Skin area was significantly correlated with BL and skin perimeter, as well as with other author's predictive formulas which take into account BW. On the basis of our preliminary results, a simple derived formula for BSA in calves could be based on BL rather than on BW. Moreover, this "body length" approach is easier and safer under field conditions.

Keywords: Allometry; area formula; regression analysis; skin area; skin perimeter

Introduction

In 1848, Bergmann in[1] attempted to explain the relatively higher heat production of smaller animals per unit of weight by the generalization that the heat production of the animal's body was proportional to its Body Surface Area (BSA). BSA is interesting for studies of energy requirements (in which the size of some organs – e.g. brain and kidneys - and metabolic processes – e.g. glomerular filtration rate - do not necessarily vary directly with BW but rather with BSA)[2] for pharmacology research (e.g. for the administration of digitalic and chemotherapeutic agents)[3,4], as an adaptive climate trait (BSA/body mass ratio increases in hotter climates and decreases in colder climates[2,3,5,6], as a step in the evaluation of burn patients[7], etc. BSA can also be used in the leather industry, as it would facilitate grading and improving.

Modern three-dimensional laser scanning technology and sophisticated graphics editing software allow a potentially accurate determination of BSA, but the equipment required is rarely available in veterinary studies. This is why BSA is still being estimated using predictive equations and currently several expressions correlating BSA with direct corporal measurements are used (see[8,9] for an interesting review for both animals and humans). For animals, the BSA is conventionally calculated using the Meeh factor times, where the volume W is scaled to two-thirds power a x W0.6728. Assuming that the specific gravity was the same in each case, Meeh substituted weight for volume so that his formula is expressed as W for body mass (BW, expressed in grams[1]) thus differing in the proportionality factor a for different species[2] Meeh's equation constitutes the base for the majority of formulas currently used to estimate BSA in domestic animals.

Earlier investigators have accepted the Meeh formula as applying to all types of animals, but later investigations proved that in many instances this formula gave very erroneous results[1]. BSA in dogs has been established as $10.1 \times BW^{2/3} \times 10^{-4}$, and for cats as $10 \times BW^{2/3} \times 10^{-4}$[9]. Trowbridge, Moulton, and Haigh[1] published a number of measurements of the BSA of cattle and calculated the constant for the Meeh formula. Their constants varied from 7.319 to 10.74, depending on the age and the degree of fatness of the animals[1].

Other estimating formulas exist, some of them using a different exponent than the one proposed by Meeh, such as those by Mitchell (1928) ($0.09 \times W^{0.69}$), Brody (1945) ($0.14 \times W^{0.57}$) and Johnson et al. (1961) ($0.235 \times W^{0.49}$) (all cited in Berman, 2003). Moulton's formula for fat cattle is $0.158 \times W^{5/8}$ and $0.1186 \times W^{5/9}$ for other species[1] Hogan and Skouby[2] considered that

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the surface area of cattle could not be accurately calculated as a power function of weight, and they therefore developed a formula to estimate BSA in cattle and swine, in which both weight and body length were factors. Their formula is BSA = $W^{0.4}$ x $BL^{0.6}$ x K, in which *W* is the live weight in kilograms, *BL* the length of the body in centimetres, and *K* a constant (217 for cattle and 175 for swine).

Evidently these formulas will all give different results, but this research does not intend to debate about which formula may or may not be better. The problem is that they are based on BW, and its correct and accurate estimation is difficult under field condition production systems, due to normal lack of weighing devices. This is why my hypothesis is to find another trait for an easy-to-take measurement for a reliable "*in vivo*" BSA estimation in cattle, such as BL. For this purpose, we studied BSA from skins obtained in a commercial abattoir, applying linear geometry by means of a capturing-area program, and from this considered "real BSA value", investigating correlations with other body traits and the other predictive formulas previously cited.

Materials and methods

Animals

During commercial slaughter of cattle in an industrial abattoir the skin is normally removed in one piece, excluding the part of the head and lower legs. A total of 40 skins from an abattoir (20 males and 20 females) aged between 205 and 396 days were studied. Animals belonged to typical European meat breeds, such as Pyrenean Brown, Charollais and Limousine, and their crosses. All of them were in good body condition and none presented apparent skin abnormalities.

Sample collection and measurements

After being removed, the fresh skins were extended on a flat floor and a picture in a vertical axis was taken for each picture. A ruler was used for each image. The skins were dressed and photographed always in the same way and included skin from udder and scrotum but no head and lower legs. Digimizer v. 4.6.1 (downloadable at http://www.digimizer.com/) was used to calculate skin area and skin perimeter, as well as body length (i.e. distance from the base of tail to base of neck). All measurements were taken by the author. Area of head and lower legs (distally from basipodium) was not included, as they had been previously separated from the body, and nor was tail area (although it appeared on each picture). Sex, age and hot carcass weight were obtained directly from the individual commercial information.

Statistical methods

Mean, range and variance were determined for all measurements. Although Kolmogorov-Smirnov test showed an unequal BSA distribution for males and females (D = 0.55, p = 0.0025), data were pooled, as the goal of this research was not to compare differences between sexes. Correlation was studied. As data distribution of skin area appeared not-normally distributed ($p < 0.05$), Spearman's correlations were determined between our skin area values and BL, skin perimeter, and calculated BSA, using Mitchell's, Brody's, Johnson's et al., Moulton's and Hogan & Skouby's formulas. On the other hand, the relationship between BL (cm) and the actual BSA (m^2) was quantified by the least squared method.

Descriptive statistics and regression analysis of each of the variables were performed using the PAST software[10]. For all tests, values of $p < 0.05$ were considered significant.

Results

Mean, range and variance for all measurements appear in Table 1. Table 2 shows estimated skin areas according to classical formulas (previously described). One must be aware that these formulas obtained BSA from carcass weight rather than from body weight, and therefore the interest is just to analyze their fitness rather than to obtain a true BSA estimation. In table 3, Spearman's correlations are shown. It appeared that skin area was significantly correlated with all other traits and all other BSA estimations, with a low negative correlation with age. The expected correlation of BSA with skin perimeter signals an evident geometrical relationship. A high correlation was found between the measured skin area and body length ($r_s = 0.643$). Evidently there is also a high correlation with skin perimeter (r_s=0.852) – a measurement that it makes no sense to obtain "in vivo" - and with Hogan's formula (r_s=0.742) – which takes into account BL for the estimation. As shown in figure 1, the power model for BSA and BL provided a significantly good fit ($r = 0.932$, $p < 0.0001$). Overall, the results indicate that the BSA of calves can be accurately predicted from the BL.

Table 1: Mean, range and variance for three measurements obtained (n=40).

	Body length (cm)	Obtained skin area (m^2)	Perimeter skin (cm)
Min	176.9	2.5	824.7
Max	306.7	8.1	1709.3
Mean	210.5	3.5	1058.255
Std. error	4.543	0.194	29.928
Stand. dev	28.733	1.228	189.283

Table 2: Estimated Body Surface Area (BSA, m^2) according to classical formulas to estimate it (see text for their detailed explanation).

	Obtained skin area	Mitchell	Brody	Johnson	Moulton	Hogan & Skouby
Min.	2.5	3.2	2.6	2.9	4.0	3.8
Max.	8.1	4.6	3.6	3.8	5.6	6.4
Mean	3.5	4.0	3.2	3.4	4.9	4.8
Stand. Dev.	1.22	0.38	0.25	0.23	0.42	0.55
Median	3.2	4.0	3.2	3.5	5.0	4.8

Table 3: Spearman's correlations using the between body length (BL), skin perimeter (Per), age and carcass weight against Body Surface Area (BSA) and estimations using formulas by Mitchell, Brody, Johnson et al., Moulton and Hogan &Skouby. p-values appear in the upper diagonal.

	BSA	BL	Per	Age	Carcass weight	Mitchell	Brody	Johnson	Moulton	Hogan & Skouby
BL	0.643		0.011		0.027	0.027	0.027	0.027	0.027	1.75×10^{-7}
Per	0.852	0.393			2.85×10^{-5}	2.85×10^{-5}	2.85×10^{-5}	2.85×10^{-5}	2.85×10^{-5}	9.24×10^{-6}
Age	N.S.	N.S.	N.S.							
Carcass weight	0.599	0.348	0.61	N.S.		0	0	0	0	4.31×10^{-13}
Mitchell	0.599	0.348	0.61	N.S.	1		0	0	0	4.31×10^{-13}
Brody	0.599	0.348	0.61	N.S.	1	1		0	0	4.31×10^{-13}
Johnson	0.599	0.348	0.61	N.S.	1	1	1		0	4.31×10^{-13}
Moulton	0.599	0.348	0.61	N.S.	1	1	1	1		4.31×10^{-13}
Hogan & Skouby	0.742	0.718	0.638	N.S.	0.867	0.867	0.867	0.867	0.867	0

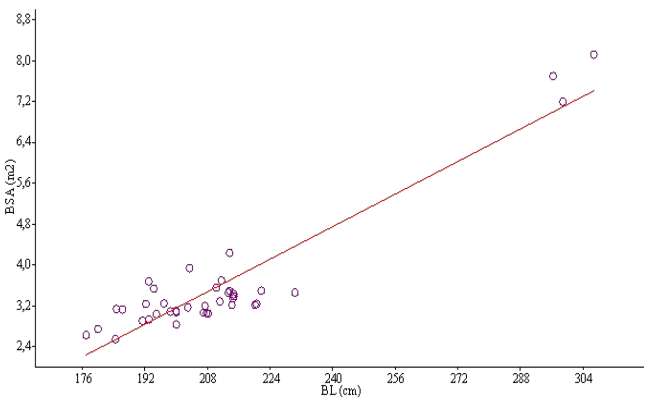

Figure 1: Relationship between Body Length (BL, expressed in cm) and the estimated Body Surface Area (BSA, expressed in m^2), quantified by the least squared method. It provided a significantly good fit (r=0.932, p<0.0001).

Discussion

Equations that estimate BSA are widely used in a variety of fields. This study highlights the need to use an equation which is "fit for purpose" for the species and age being assessed, in particular, meat-purpose calves ranging from ca. 21-33 months of age.

Because BW is influenced by body condition score [11], anatomical measurements, as indicators of skeletal size, may reflect the true size of replacement heifers better than BW. Moreover, equations suggested by Mitchell, Brody, Johnson et al. and Hogan and Skouby were developed on the basis of measurements made some decades ago. Since then, cattle size has undoubtedly increased owing to genetic (and perhaps also environmental) changes. It is thus possible that the relation of BSA to BW may have been altered, which may reduce the applicability of these equations.

On the basis of our preliminary results, the recommended simple derived formula for BSA in calves had to be based on body length rather than on body weight, which represents the independent variable considered for currently used formulas. The trait is easy to obtain in live animals. The most direct way to weigh animals individually is to use a traditional or electronic scale.

However, this direct measurement requires equipment rarely available in field conditions (especially under pasture-based production systems, where facilities for handling and working are usually limited). Apart from the conventional use of a scale in determining the weight of cattle, weight determination by estimating some linear parameters can be employed. Thoracic perimeter ("heart girth", the circumference taken around the chest just behind the front legs and withers) is a classical body trait for estimating body weight[12,13]. Measuring thoracic dimension in live animals can, however, be an awkward process which may involve a high risk of injury to people. Moreover, numerous drawbacks can be reported, such as precision errors due to patient movement, and the fact that the estimates are based on the cylinder shape approximation and axis-oriented formation of the animal body, which is not totally true, thus reducing accuracy for the BSA estimation. One could argue that weight may be estimated from various other body measurements (e.g. wither height, hip height, etc.)[11], but again this "double estimation of BSA" would increase the error. Under this scenario, BL is simple to obtain due to its easily identifiable anatomical locations (from base of neck to base of tail), its ease and safety on accessing the animal (measurement is performed on the dorsal face of the body) and to the fact that it requires no complete restraint of the animal (it can be undertaken in a corridor). It thus appears to be a good "on field" estimator of BSA by equations.

It would therefore seem that "classical" formulas using that trait do not fit very well on estimating BSA. The higher correlation between the measured skin area and body length justifies the use of a formula based on body length rather than body weight), at least in growing animals.

However, it is important to make some considerations with regard to the scope of usage of an estimation power based on BL. Firstly, there was an underestimation of the BSA because distal parts (skin of the head and lower legs) were not considered, but the purpose of this study was the study of correlation, not the establishment of real values. Secondly, this study was performed with animals from 17 to 33 months of age; in this interval, BL is not correlated with age, so no age-correction should be undertaken. However, its mathematical behaviour remains unknown under or above that age range.

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