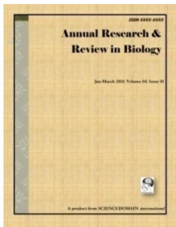

Annual Research & Review in Biology
4(2): 354-365, 2014

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Relationship among BCS and Fat Thickness in Horses of Different Breed, Gender and Age

P. Superchi[1], I. Vecchi[1], V. Beretti[1] and A. Sabbioni[1*]

[1]Department of Veterinary Science, University of Parma, Via del Taglio 10, 43126, Parma, Italy.

Authors' contributions

This work was carried out in collaboration between all authors. Authors contributed equally to the paper. All authors read and approved the final manuscript.

Original Research Article

Received 18th September 2013
Accepted 9th October 2013
Published 19th October 2013

ABSTRACT

Aims: The aims of the study were to investigate i) the kind of the relationship among BCS and subcutaneous fat thickness (FT) in horses, as affected by breed, gender and age, and ii) the effectiveness of a combination of the two variables in order to better estimate adiposity.

Study Design: Body weight (BW), FT (at croup level, by means of an ultrasound device) and BCS (5 point scale) were recorded in 124 horses (55 Standardbred; 25 Italian Saddler; 44 Thoroughbred) of different gender (95 mares; 14 stallions; 15 geldings) and age (26 ≤4 years of age; 98 >4 years of age) at five commercial herds.

Methodology: After at least one hour from the morning meal, BW, by means of an electronic balance, and FT on the croup, at approximately 11 cm cranial to the tail head and 10 cm lateral to the midline, by means of an ultrasound device (Lean-Meater, Renco Corporation) were recorded. BCS was evaluated at the same moment on a scale of 1 to 5 (1 = emaciated and 5 = extremely obese).

Results: BCS was affected by breed (P<.05), while FT was independent of breed, gender and age (P>.05). Overall FT and BCS were moderately correlated (r=0.335; P<.01); correlation coefficients were higher in Italian Saddler (r=0.549; P<.01), stallions (r=0.631; P<.05), and young horses (r=0.539; P<.01). A new variable (FT_BCS), calculated as (FT*BCS)/(FT+BCS), is proposed. It resulted correlated both to FT (r=0.754; P<.01) and BCS (r=0.824; P<.01). Allometric coefficients of FT and BCS on BW were of the same sign, regardless of sex and breed, as mature horses tended to decrease FT and increase BCS

**Corresponding author: Email: alberto.sabbioni@unipr.it;*

with the increase of BW; coefficients for FT_BCS on BW gave a better fit than FT or BCS alone, as in Thoroughbred and in young horses they gave a better fit than both FT and BCS.

Conclusion: The study showed that, due to their correlation, BCS or FT alone could be not sufficient to describe horse body adiposity, but their association could be more useful; in the weight range between 470 and 500 kg, their combination is able to appreciate a deviation from linearity of the allometric equation with BW in geldings and Italian Saddler horses.

Keywords: Horse; BCS; fat thickness; allometry.

1. INTRODUCTION

The body condition, defined by Murray [1] as the ratio of body fat to non-fat components in the body of a live animal, is a prerequisite to ensure a health status, productivity, and reproductive efficiency in horses [2,3,4,5,6,7,8]. In all healthy animals, body fat storage is important because fat represents the amount of the energy reserves the animal has for periods of poor energy availability. The variability in fat mass is related to the genetic status of the individual horse, as far as to environmental factors, such as exercise, training or nutrition. As a result, several systems to subjectively or objectively appraise the stored energy reserves of horse have been introduced. In the first case, scores are assigned to reflect the degree of apparent adiposity of specific anatomical areas of the horse; these scores are termed as body condition score (BCS). In the second case, equipments are used to estimate the fat reserves.

Usually body condition is evaluated through visual and tactile appraisal, on a scale ranging from 1 to 9 [9] or from 1 to 5 [10]. Irrespective of the scale used, low values reflect emaciation and high values equate to obesity. When properly applied, the scoring system is independent of size or conformation of the horse [9]. Unfortunately, most of the BCS systems reported for production animals have been constructed with more concern for inter- and intra-observer agreement than with their validity in terms of their ability to measure body fat. Studies carried out under experimental conditions on a limited number of animals have shown that the BCS is correlated to body fat percentage in mares (r=0.65-0.87) [9,11] and in jennies (r=0.65-0.86) [12] and to the weight of total, subcutaneous, internal or intramuscular fat tissues (r=0.986-0.990) in sport horses [13].

Ultrasound is another non-invasive technique for the measurement of body composition which has several advantages, compared to BCS. It is an objective, highly repeatable, precise, accurate and easy to perform evaluation for the estimate of body composition in all populations and it can be used for percent body fat evaluation [14,15]. Other methods have been proposed and include dissection and chemical analysis (a destructive, but gold standard technique) or D_2O dilution (a minimally invasive technique) to actually quantify body fat content [16,17,18].

Large-scale direct measurements of horse body adiposity evaluation under field conditions has become an important issue because of the economic pressure to achieve optimal production and reproduction targets.

Maes et al. [19] report that the two techniques measure different aspects of the body condition. Ultrasound fat measurement constitutes a tool to evaluate the total amount of body fat, while the apparent adiposity assessed by visual scoring may not only depend upon the amount of fat thickness, but it may also be influenced by the amount of muscles. Moreover it has been observed that BCS, with particular emphasis on the amount of fat in areas such as the tail head, can provide an accurate estimate of the condition and/or body fat content [14, 20]. The results obtained under experimental conditions, on a limited number of subjects, even of the same sex and of the same breed, however, sometimes could not be confirmed by an assessment of body adiposity performed under field conditions. Earlier studies carried out under farming conditions in swine herds, have shown only a moderate correlation (r=0.30-0.60) between visual scoring of body condition and ultrasound measurements of subcutaneous fat [19]. The issue is that, often, it is not easy to evaluate the body condition in an objective way under practical circumstances, both because largely depending upon the scoring skills of the person and because, when visual scoring is performed by the same person over time, it is likely that less attention will be paid to deviations from the optimal condition.

The aims of the study were to investigate i) the kind of the relationship among BCS and subcutaneous fat thickness in horses, as affected by breed, gender and age, and ii) the effectiveness of a combination of the two variables in order to better estimate adiposity in horses.

2. MATERIALS AND METHODS

The study is based on routinely collected data from horse herds in Italy, under the control of public veterinary authorities.

2.1 Animals

One hundred twenty-four horses (55 Standardbred; 25 Italian Saddler; 44 Thoroughbred) of different gender (95 mares; 14 stallions; 15 geldings) form five different herds participated in the study. The overall population was represented by horses of two classes of age (≤4 years of age: no. 26; >4 years of age: no. 98). Among mares, 80% were in reproductive activity (lactating and/or pregnant, in different phases) and were housed in individual box stalls at night and in groups in a paddock during the day; the remaining mares, as far as males and geldings were in sport activity and were always penned. The latter group performed a daily workout for about 1-2 hours, depending on competitive programs to meet the planned objectives. Horses were fed three times/day (morning, midday, evening); those in reproductive activity received a diet with a forage/concentrate ratio of 65/35 on dry matter; those under sport activity received a diet with a forage/concentrate ratio of 50/50 (Standardbred and Thoroughbred) or 60/40 (Italian Saddler) on dry matter.

2.2 Measures

After at least one hour from the morning meal, the BW, by means of an electronic balance (Gilmar, Gropello Cairoli, Pavia, Italy) (0.01 kg approx.), and the subcutaneous fat thickness (FT) on the croup, 11 cm cranial to the tail head and 10 cm lateral to the midline, by means of an ultrasound device (Lean-Meater, Renco Corporation) [14] were recorded. The equipment was set in channel 1 and vaseline oil was used on shaved skin. The sensitivity was 4-35 mm. Body condition score was evaluated at the same moment, on a scale of 1 to 5

(1 = emaciated and 5 = extremely obese) [10]. The information from both FT and BCS were then combined into a new variable, named FT_BCS, calculated in the following way: FT_BCS = (FT*BCS)/(FT+BCS). Several combinations of FT and BCS were previously tested and FT_BCS was chosen for its highest correlation.

2.3 Statistical Methods

Data were submitted for analysis of variance [21] after check for normality, with herd, breed (within herd), sex, age-class and interactions as fixed factors. Moreover, a Pearson correlation analysis was performed among variables on raw data and on residuals obtained after the application of the above mentioned model. Allometric coefficients were then calculated for each sex, breed and age-class, by applying the allometric equation: $y = ax^b$, where "y" was the dependent variable (FT, BCS, FT_BCS) and "x" the independent variable (BW), "a" was the intercept and "b" the allometric coefficient. Allometry describes how a trait scales with one another. In this case, values of the allometric coefficient >1 were considered as positive allometry or hyperallometry, and mean that adiposity indicators grow at a higher rate than BW; values <1 were considered as negative allometry or hypoallometry, and mean that adiposity indicators grow at a lower rate than BW, as isometry was the condition of the growth of two traits at the same rate [22].

3. RESULTS AND DISCUSSION

Mean values, SD, minimum and maximum values and coefficient of variation (CV) for age, BW, BCS, FT and FT_BCS are shown in Table 1. A high variability was obtained for all variables, particularly for FT, but the wide range of values indicates that the population is representative of the field conditions of horse breeding.

Table 1. A descriptive statistics of parameters obtained from horses used in the study (n = 124)

Item	Mean ± SD	Minimum	Maximum	CV %
Age (years)	9.46 ± 5.31	2	24	56.1
BW [a] (kg)	504.96 ± 59.04	350.0	628.9	11.7
BCS [b]	2.95 ± 0.58	1.5	4.5	19.7
FT [c] (mm)	11.76 ± 5.35	3	29	45.5
FT_BCS [d]	2.27 ± 0.50	1.15	3.43	21.8

*a: Body Weight; b: Body Condition Score; c: Fat Thickness; d: (FT*BCS)/(FT+BCS)*

The least squares means for BW, BCS, FT and FT_BCS in relation to breed, gender and age-class are reported in Table 2. The assessment of adiposity by means of ultrasound measurements was rather independent of breed, gender, and age-class (P>.05). On the contrary, the visual scoring of the body condition was affected by breed (P<.05) but not by gender and class of age (P>.05). Also FT_BCS was affected by breed, the highest values being reported for Thoroughbred and the lowest by Standardbred (P<.05).

In our study, the Italian Saddler horse was not significantly different from Standardbred with reference to BW and FT, but significantly different with concern to BCS. The definition of the new variable FT_BCS reduced the difference between the two breeds, from 21.32% (P<.05) to 18.72% (P>.05), respectively for BCS and FT_BCS. This is valuable also at gender level, also if differences were never significant (P>.05). Geldings resulted lighter (-6.27%) but with higher FT (+20.66%) than mares. Nevertheless, their BCS resulted lower than mares (-3.67%), probably because the lower weight affected the judgement of the evaluators. Also in this case the proposed new variable allowed to better define the differences among animals, keeping into account the higher fat content (-3.83%).

Table 2. Least Squares means of morphologic traits as affected by breed, gender and age-class

	Breed			Gender			Age-class (years)		RSD	R^2
	SB [e]	IS [e]	TB [e]	M [e]	S [e]	G [e]	≤ 4	> 4		
BW [a] (kg)	438.8	498.9	476.2	485.2	473.9	454.8	436.4	506.2	36.0	0.642
BCS [b]	2.58 f	3.13 g	3.32 g	3.00	3.14	2.89	3.03	3.00	0.50	0.264
FT [c] (mm)	10.03	15.05	13.82	12.34	11.67	14.89	13.71	12.22	5.21	0.035
FT_BCS [d]	2.03 f	2.41 fg	2.55 g	2.35	2.29	2.26	2.37	2.23	0.45	0.126

*a: Body Weight; b: Body Condition Score; c: Fat Thickness; d: (FT*BCS)/(FT+BCS); e: SB = Standardbred; IS = Italian Saddler; TB = Thoroughbred; M = mare; S = stallion; G = gelding; f, g: P<.05*

Several factors affect adiposity in horses, besides breed, gender and age. They involve some management factors (type of work, feeding level, reproductive exploitation for stallions and mares, presence of parasites), besides environmental and individual factors. Moreover, by the application of regression analysis, Christie et al. [23] showed that also the date of examination, the years owning horses and the membership of a horse related organization are significant factors affecting BCS. The maintenance of an optimal body condition has been considered as an important factor of animal physical welfare [24], and the achieving of good reproductive [8] and sporting performance depends largely on it.

Low correlation coefficients were calculated among BW and adiposity traits (Table 3) except for geldings and young horses. In geldings high and significant (P<.01) correlation coefficients were calculated between BW and BCS or FT_BCS. This result was in part expected because BW is represented by fat tissues, lean tissues and bones. The castration markedly increases fat deposition in horses, as far as in other species [25]. In young horses, correlation coefficients were high and positive, both for raw data (P<.01) and for residuals (P<.05). There was a moderate overall correlation (r=0.335; P<.01) between BCS and FT. When the same correlation was calculated on residuals, then the r value rose to 0.402 (P<.01), thus indicating that removing factors contained in the model is an advantage for the understanding of the relationships between the different estimates of adiposity. The correlation coefficients between BCS and FT varied widely among breed, gender and class of age. Among breeds, the highest correlation coefficients have been recorded for Standardbred (r=0.529; P<.01) and Italian Saddler (r=0.549; P<.01) and the lowest for Thoroughbred (r=0.170; P>.05). In relation to gender, BCS was significantly correlated to FT in mares (r=0.296; P<.01) and in stallions (r=0.631; P<.05) but not in geldings (r=0.510; P>.05). In relation to age-class, in young horses (≤ 4 years) the correlation coefficient was 0.539 (P<.01) while in the oldest it was lower (r=0.298; P<.01). In general, the correlation coefficients calculated on residuals gave results similar to those calculated from raw data, with the exception of the coefficients of stallions, that improved from 0.631 (P<.05) to 0.712 (P<.01). The new variable FT_BCS was always highly correlated (P<.01) to BCS and to FT, both for raw data and for residuals.

Table 3. Pearson correlation coefficients on raw data and on residuals among BW, BCS, FT and FT_BCS in horses of different breed, gender, and age-class

		Raw data			Residuals		
		BCS[b]	**FT[c]**	**FT_BCS[d]**	**BCS**	**FT**	**FT_BCS**
BW [a]							
Overall		0.135	0.057	0.055	0.020	0.047	0.001
Breed	Standardbred	0.069	0.258	0.121	-0.012	0.100	0.030
	It. Saddler	-0.081	-0.390	-.0298	0.193	-0.076	0.034
	Thoroughbred	-0.119	-0.007	-0.202	-0.001	0.051	-0.052
Gender	Mare	0.167	0.058	0.082	0.002	0.048	-0.022
	Stallion	-0.302	-0.055	-0.265	-0.019	0.221	0.073
	Gelding	0.827**	0.223	0.673**	0.401	-0.130	0.213
Age-class	≤4 years	0.649**	0.560**	0.675**	0.436*	0.503*	0.488*
	> 4 years	0.090	-0.079	-0.034	-0.031	-0.007	-0.061
BCS							
Overall		-	0.335**	0.824**	-	0.402**	0.810**
Breed	Standardbred	-	0.529**	0.918**	-	0.548**	0.914**
	It. Saddler	-	0.549**	0.842**	-	0.536**	0.863**
	Thoroughbred	-	0.170	0.648**	-	0.166	0.636**
Gender	Mare	-	0.296**	0.809**	-	0.375**	0.791**
	Stallion	-	0.631*	0.922**	-	0.712**	0.938**
	Gelding	-	0.510	0.927**	-	0.378	0.870**
Age-class	≤4 years	-	0.539**	0.951**	-	0.570**	0.916**
	> 4 years	-	0.298**	0.790**	-	0.378**	0.795**
FT							
Overall		-	-	0.754**	-	-	0.806**
Breed	Standardbred	-	-	0.791**	-	-	0.813**
	It. Saddler	-	-	0.847**	-	-	0.824**
	Thoroughbred	-	-	0.789**	-	-	0.799**
Gender	Mare	-	-	0.748**	-	-	0.811**
	Stallion	-	-	0.870**	-	-	0.902**
	Gelding	-	-	0.783**	-	-	0.769**
Age-class	≤4 years	-	-	0.765**	-	-	0.839**
	> 4 years	-	-	0.761**	-	-	0.802**

*a: Body Weight; b: Body Condition Score; c: Fat Thickness; d: (FT*BCS)/(FT+BCS); * P< .05; ** P<.01*

In the present study sometimes BCS and FT do not agree and consequently it is difficult to properly use the information about body fatness. Recently, Quaresma et al. [12] found that the log transformation of both BCS and real time ultrasonography gave a slight better correlation between variables than raw data. Usually, body condition is evaluated by owners and veterinarians by visual scoring system, but the moderate correlations observed in the present study showed that the assessment of the BCS alone could not always provide a reliable picture of the body fat, as a correction of BCS for fat thickness, as proposed by the new variable FT_BCS, could improve the assessment of adiposity.

The static allometric coefficients of adiposity traits (FT, BCS, FT_BCS) on BW are reported in Table 4. Allometric coefficients of FT and BCS on BW were of the same algebraic sign, regardless of gender and breed, as older horses decrease FT and increase BCS with the increase of BW. Overall allometric coefficients for FT, BCS and FT_BCS were <1 (0.113-0.239). Fat thickness grew faster, in relation to BW in Standardbred (b=0.880) than in

Thoroughbred (b=-0.029) and Italian Saddler (b=-1.648), in geldings (b=1.001) than in other sexes (values of b from 0.247 for mares to -0.101 for stallions), and in young horses (b=2.857) than in older (b=-0.446). The allometric equations of BCS gave in general a better fit than FT, with the exclusion of Italian Saddler and Standardbred. Allometric coefficients for FT_BCS on BW gave a better fit than FT or BCS alone, as in Thoroughbred and in young horses they gave a better fit than both FT and BCS.

Table 4. Allometric coefficients (b) and goodness of fit (R^2) of FT, BCS and FT_BCS on BW as affected by breed, gender and age-class in horse

		FT		BCS		FT_BCS	
		b	**R^2**	**b**	**R^2**	**b**	**R^2**
All		0.239	0.004	0.228	0.019	0.113	0.004
Breed							
	Thoroughbred	-0.029	0.000	-0.152	0.014	-0.310	0.041
	Italian Saddler	-1.648	0.122	-0.148	0.006	-0.833	0.086
	Standardbred	0.880	0.067	0.116	0.005	0.224	0.015
Gender							
	Mare	0.247	0.004	0.309	0.028	0.170	0.008
	Stallions	-0.101	0.001	-0.346	0.066	-0.358	0.050
	Geldings	1.001	0.049	1.217	0.679	1.185	0.448
Age-class							
	≤4 years	2.857	0.350	1.891	0.432	1.945	0.471
	>4 years	-0.446	0.002	0.203	0.007	-0.102	0.006

The allometric model tested in the study was a static model, comparing different animals at the same stage of growth. So the overall allometric coefficients for FT, BCS and FT_BCS on BW were <1. Only in young horses, with an age ≤4 years, the coefficients were >1, as assessed also for growing animals in other species, as pigs [26,27] or lambs [28]. Low R^2 values were showed by allometric equations, except for BCS and FT_BCS of geldings and for equations of young horses. This was expected because the study was conducted at field level, on a sample of animals not homogeneous for breed, gender and age.

Figs. 1 A, B, C, Figs. 2 D, E, F and Figs. 3 G, H, I report the shape of the allometric relationship between BW and FT, BCS and FT_BCS as affected by gender, breed and class-age, respectively. As FT and BCS relationship with BW was generally linear (Fig. 1 A, B, and Figs. 2 D, E), regardless to gender and breed, FT_BCS (Fig. 1 C and Fig. 2 F) showed a non linear shape in the weight interval between 470 and 500 kg in geldings (higher speed) and in Italian Saddler (lower speed). Adult horses showed an opposite shape of the curve relating FT and BW (decreasing; b=-0.446) or BCS and BW (increasing; b=0.203) (Figs. 3 G, H). When corrected for FT, BCS decreased as BW increased (b=-0.102) (Fig. 3 I), so allowing to improve the management and consequently the welfare of older horses.

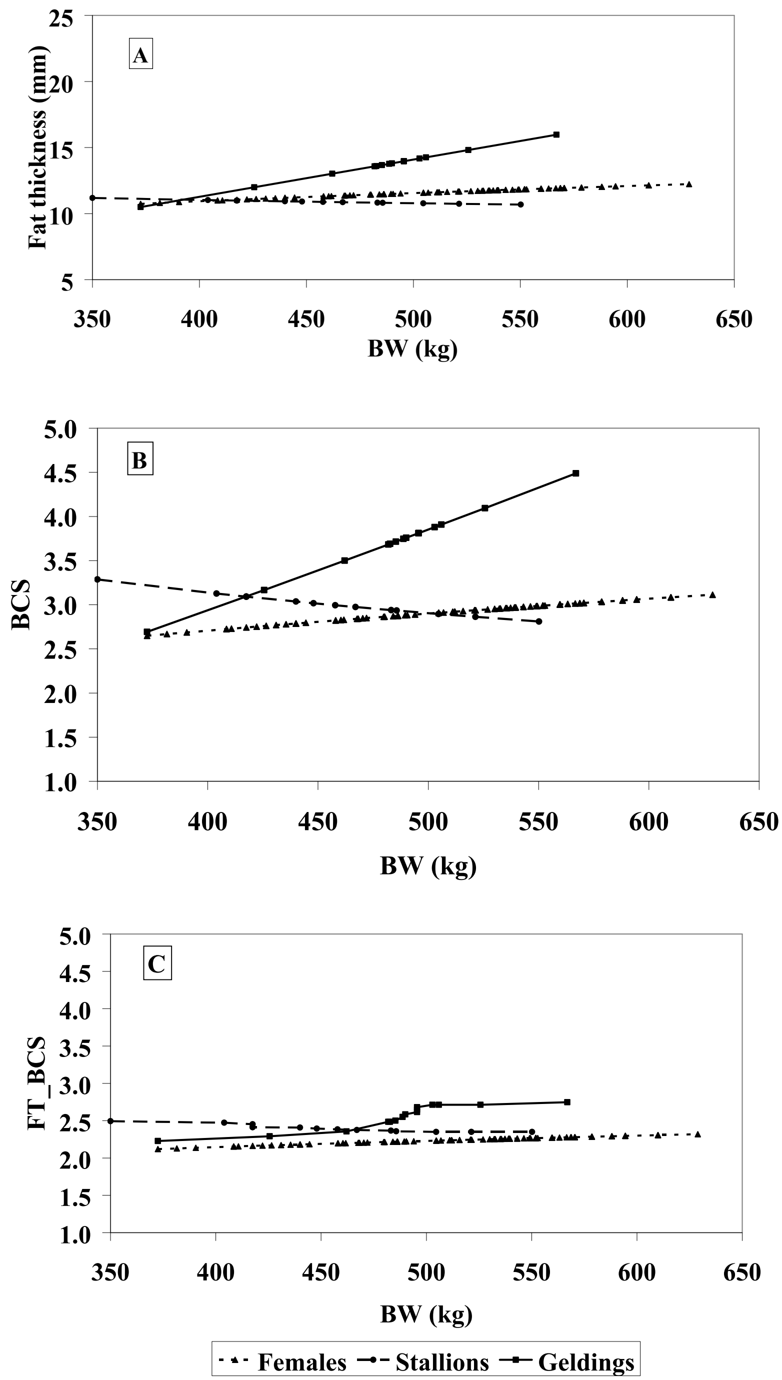

Fig. 1. Allometry of FT (A), BCS (B) and FT_BCS (C) on BW in relation to gender

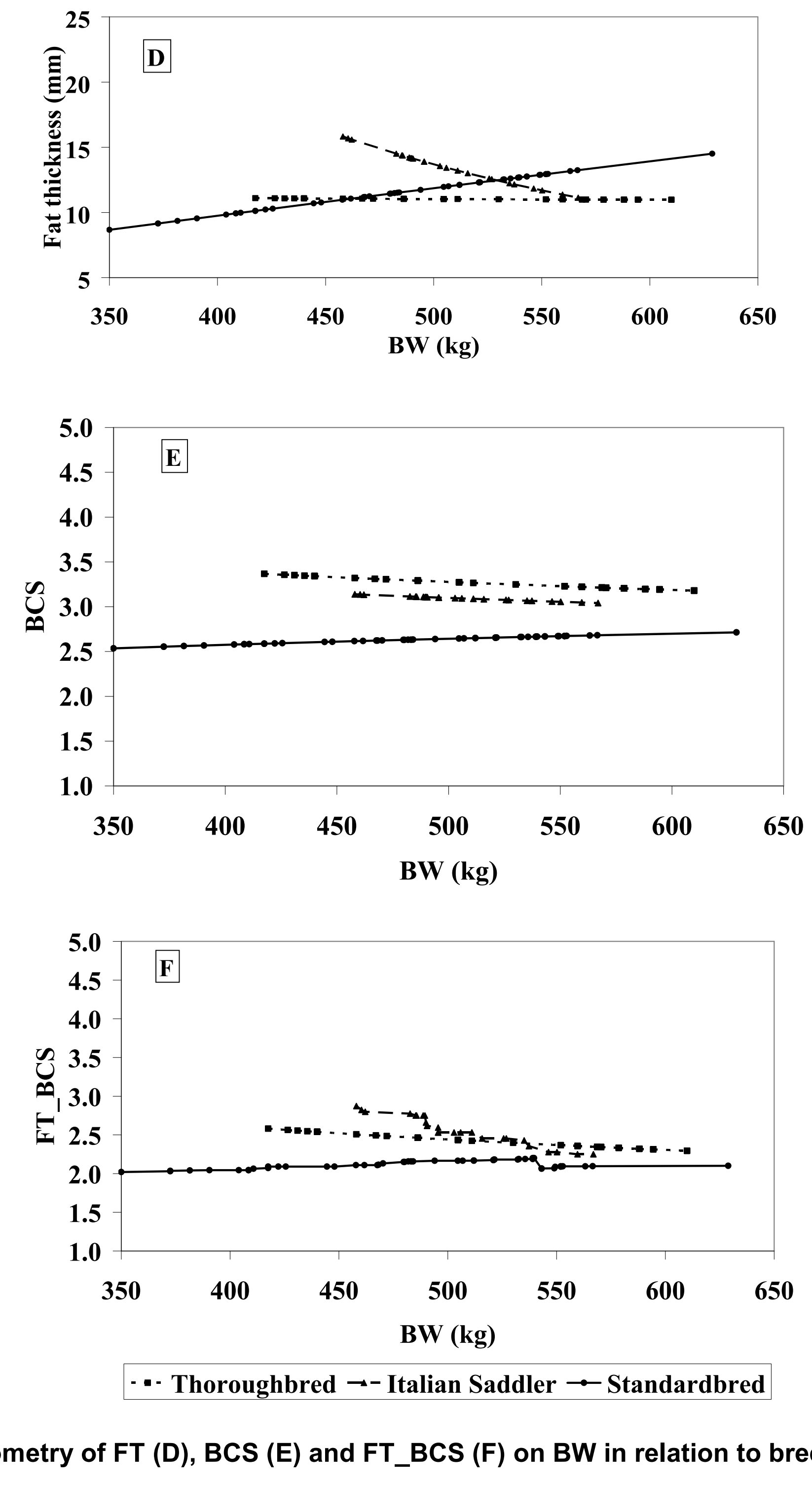

Fig. 2. Allometry of FT (D), BCS (E) and FT_BCS (F) on BW in relation to breed

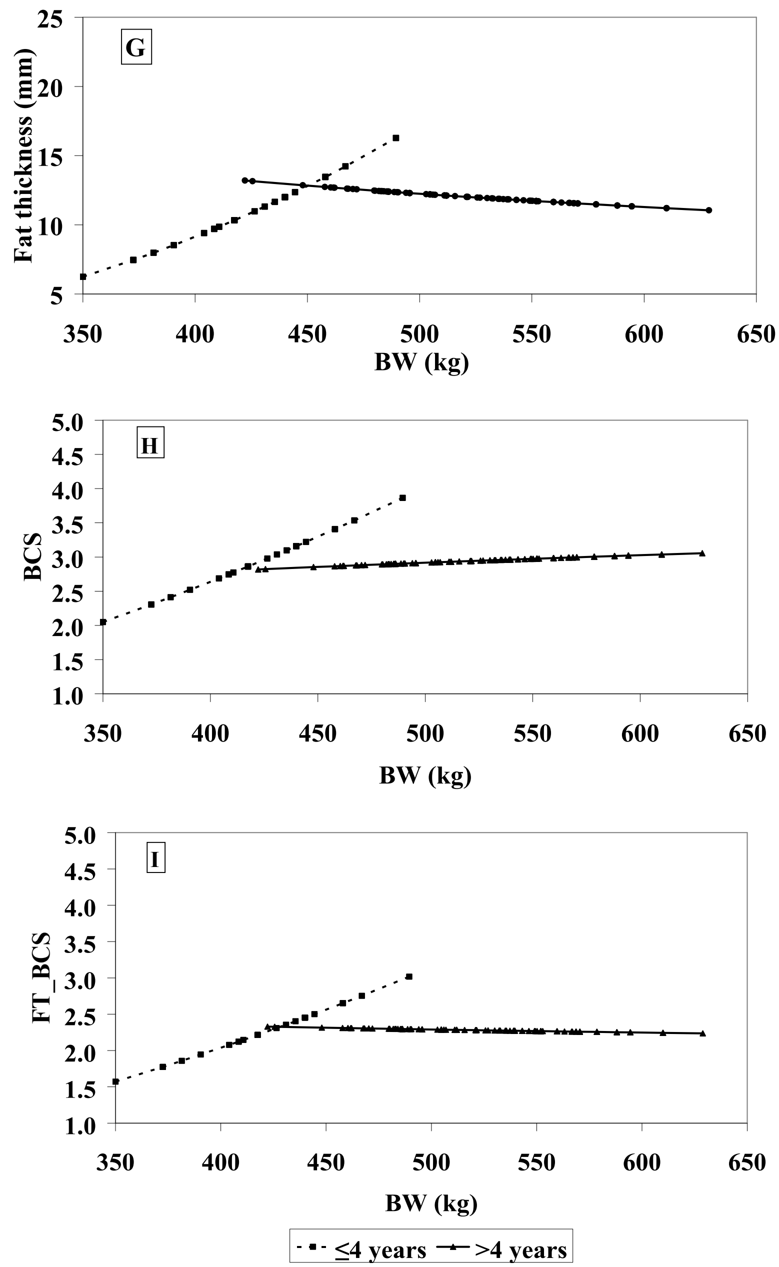

Fig. 3. Allometry of FT (G), BCS (H) and FT_BCS (I) on BW in relation to age-class

4. CONCLUSION

In conclusion, we could assert that both subjective BCS and objective assessment of subcutaneous fat thickness are valuable ways to estimate the adiposity in horses; however, under field conditions, when there is the need to answer to a negative energy balance through appropriate feeding or to avoid an excessive fat deposition, due to the lack of linearity in specific moments, the association of the two measurements would be more accurate and useful. In particular, in the weight range between 470 and 500 kg, the new variable FT_BCS is able to appreciate a deviation from linearity of the allometric equation with BW in some categories (geldings, Italian Saddler), that was not showed by FT or BCS alone.

COMPETING INTERESTS

Authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.

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