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RESEARCH ARTICLE

Body Measurements and Body Condition Scoring as Basis for Estimation of Live Weight in Nili-Ravi Buffaloes

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ABSTRACT

Implementation of management recommendations for the Nili-Ravi buffalo in small- and medium scale commercial dairy production systems in Pakistan is hampered by difficulties to determine body weight (BW) of the animal. A workable and reliable method of predicting BW of this breed by using body measurements and body condition scoring (BCS) was therefore explored. Nili-Ravi buffaloes (n=211) were divided into three age groups (1-3 years = G1; >3-8 years = G2; >8 years = G3). Animals were weighed on a mechanical scale and their heart girth (HG), body length (BL) and shoulder height (SH) were measured. In addition, BCS was performed using a 5 point scale. Recorded data were subjected to simple and multiple linear regression analysis. The overall mean values of BW, HG, BL, SH and BCS were 359±160.9 kg, 170±30.1 cm, 130±19.2 cm, 125±14.5 cm and 3.8±0.77. With correlation coefficients (r) of 0.97 (HG), 0.94 (BL), 0.93 (SH) and 0.43 (BCS), the relationship between the individual independent variable with BW were significant ($P<0.01$) in all cases. The multiple linear regression between BW and HG, BL and BCS was highly significant ($P<0.001$) for each of the three groups (G1: $r^2=0.95$, G2: $r^2=0.86$, G3: $r^2=0.83$). Buffalo farmers who lack mechanical or electronic scales to regularly determine BW of their animals can thus combine simple morphometric body measurements (HG, BL) with BCS or just rely on HG in order to calculate feed requirements, monitor growth, determine breeding age, marketing weight and estimate the animals' cash value.

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INTRODUCTION

The domestic buffalo plays an important role in the agricultural economy of many tropical and sub-tropical countries. In Pakistan, buffaloes, because of their higher milk fat content than cattle, are mostly reared on small-scale farms that self-consume most of produced milk but sell the surplus to complement the family budget. During recent years, rearing dairy buffaloes has gained momentum in Pakistan, and the number of commercial dairy farms has shown a tremendous increase (Khan *et al*., 2008). In addition, the buffalo is also an important source of meat, mainly through culled adult females, males and male calves (Suhail *et al*., 2009).

Determination of body weight (BW) of an animal is necessary to calculate its feed requirements, monitor growth, determine breeding age, marketing weight and estimate its cash value (Payne, 1990; Erat, 2011). In Pakistan, however, small-and medium-scale buffalo owners depend on eye-judgment when assessing body weight. Managerial decisions are, therefore, mostly based on rough and inaccurate weight estimates. Animal weighing instruments are costly to obtain, heavy to transport and need technical maintenance which often is beyond the reach of smallholders (Abdelhadi and Babiker, 2009).

Body weight depends on various genetic and environmental factors; among the former are body size and other morphometric traits which are also associated with productivity (Shankar and Mandal, 2010). Morphometric measurements are simple and easy to conduct, and allow estimating the animal's BW with reasonable accuracy. However, these approaches are prone to errors in the localization of reference points and may be biased by anatomical distortion due to animal movement (Sowande and Sobola, 2008). Nevertheless, body measurements have been used to evaluate breed performance and characterize various types of ruminants. Msangi *et al*. (1999) reported that heart girth (HG) can be used with great accuracy for estimating the BW of all classes of dairy cattle, and for various buffalo breeds a high correlation between HG and BW was also reported (Table 1). Other authors reported a good relationship between the body condition score (BCS) and BW of cattle (Nesamvuni *et al*., 2000; Abdelhadi and Babiker, 2009). The body condition score system classifies the condition of an animal through the visual assessment of its subcutaneous fat cover especially on the back and pelvic regions (Nelson *et al*., 1985). Although the technique is simple to perform, it is subjective and requires expertise (Msangi *et al*., 1999); moreover, it is influenced by feeding regime and parity (Roche *et al*., 2009).

Given limited choice among equations for estimating the body weight of river buffalo, especially the economically important Nili-Ravi breed, from morphometric measures and/or BCS, and their undisclosed or low correlation coefficients (Table 1), we aimed to (i) combine easy-to-determine body measurements and BCS to reliably estimate BW of Nili-Ravi buffaloes and (ii) assess, from a theoretical point of view, the ease of using the established equations for management decisions on small-and medium-scale dairy farms.

MATERIALS AND METHODS

Study location and environmental conditions: The data were collected from buffaloes maintained at the Livestock Experimental Station Bahadurnagar, Okara, Pakistan (30°48'5" N, 73°26'54" E). This station is a semi-intensively managed farm aiming to conduct problem-oriented research for the enhancement of milk and meat production from Nili-Ravi buffaloes and Sahiwal cattle. The study was conducted during the month of September 2011, when the average maximum daily temperature was 34°C, and relative humidity averaged 66%.

Morphometric measurements and body condition scoring: A total of 211 Nili-Ravi buffaloes were divided into three age groups: 1-3 years (G1; n=84), >3-8 years (G2; n=94) and above 8 years (G3; n=33). After overnight fasting, they were weighed on a mechanical scale (range 0-1000 kg, accuracy 1 kg). Afterwards, measurements (in cm) were taken of their heart girth (HG: plastic tape drawn around behind the front legs, measured from a point slightly behind the shoulder blade, down the fore-ribs), body length (BL: average length from the head of the humerus to the end of the posterior on each side, measured with a plastic tape), and shoulder height (SH: distance from the surface of the soil/platform to the dorsal point of the withers, measured with a stick-rule), with the animal standing on a level platform. Body condition scoring was performed using the 1-5 point scale (with 0.5 point intervals) proposed by Abeygunawardena *et al.* (1999). Additional data regarding animal age and lactation number were also recorded.

Statistical analysis: The collected data was tested for normality and subjected to descriptive statistics (one-way ANOVA) and simple and multiple linear regression analysis using the Statistical Package for Social Sciences version 17.0 (SPSS Inc. 2007).

RESULTS AND DISCUSSION

Across the three age groups, the simple linear regression between BW and BCS, as well as between BW and HG, BL, and SH, was positive and significant (Fig. 1). This was also true for the simple linear regression between BW and BCS, HG, BL and SH for each individual age group (Table 2), with the highest accuracy of BW estimation was achieved from HG measurements. For the three age groups the regression equations between BW (y, kg) and HG (x, cm) were as follows:

G1: $y = 0.270\,x + 85.91 \quad R^2 = 0.94$ [Eq. 1]

G2: $y = 0.124\,x + 131.9 \quad R^2 = 0.80$ [Eq. 2]

G3: $y = 0.108\,x + 143.1 \quad R^2 = 0.71$ [Eq. 3]

The comparison among different age groups of Nili-Ravi buffaloes (Table 3) yielded highly significant (P<0.001) differences, for all variables, the values being highest in group G3, intermediate in group G2 and lowest in group G1.

The multiple linear regression between BW and HG, BL and BCS was highly significant (P<0.001) for each of the three groups. The equations are given in Table 4,

Table 1: Geographical distribution of studies carried out on buffalo in different countries to estimate body weight (dependent variable Y, in kg) using formulae derived from various body measurements (independent variables, in cm)

Country, Reference	Breed/type (n)		Regression equation	R^2
Pakistan, Khan *et al.* (1978)	Nili Ravi buffalo (350)	a)	2 - 5 years: Y = -1697.226+16.761 SH + 23.947 HG+0.514 BL	n.g.
		b)	>5 - 8 years: Y = -1604.790+ 1.268 SH + 30.902 HG+3.960 BL	
		c)	>8 years: Y = -1263.663+ 8.060 SH + 18.924 HG+8.565 BL *Y in pounds, SH, HG, BL in inches*	
India, Bhakat *et al.* (2008)	Water buffalo (268)		Y = -611.70+1.69 HG+2.45 AG+ .50 BL+0.47 CRL +1.78 DPN- 1.10 DHK+3.36 DPH+0.02 HW-1.77 HH	0.67
Indonesia, Murti (2002)	Water buffalo (n.g.)		Y = 5.03 BL-298.27	n.g.
Iran, Taheri Dezfuli *et al.* (2010a)	Water buffalo (180)		Y = -670.831+621.4 HG	0.96
Iran, Taheri Dezfuli *et al.* (2010b)	Water buffalo (2083)	a)	male: Y = -755.929+6.761 HG	0.97
		b)	female: Y = -642.061+6.015 HG	0.97
Central Java, Johari *et al.* (2009)	Swamp buffalo (100)	a)	male: Y = - 601.8+2.3 BL+3.4 CD+2.4 CC	0.91
		b)	female: Y = - 644.5+2.8 BL+1.6 CD+2.9 CC	0.95
Vietnam, Berthouly (2008)	Swamp buffalo (n.g.)	a)	male: Y = -686.11+6.2080 HG	0.88
		b)	female: Y = -464.69+3.5527 HG	0.80

n.g.: not given; AG = Abdominal girth, BL = Body length, CC = Chest circumference, CD = Chest depth, CRL = Crown rump length, DHK = Distance between hooks, DPH = Distance between pin and hook, DPN= Distance between pins, HG = Heart girth, HH = Height at hook, HW = Height at withers, SH = shoulder height.

Table 2: Correlation coefficients between body weight, age and various body measurements of different age groups of Nili-Ravi buffaloes

Variables	Age group			
	G1 (1–3 yrs)	G2 (>3-8 yrs)	G3 (> 8 yrs)	All groups
No. of animals	84	94	33	211
Heart girth (cm)	0.971*	0.89*	0.843*	0.966*
Body length (cm)	0.928*	0.809*	0.592*	0.939*
Shoulder height (cm)	0.950*	0.837*	0.628*	0.934*
Body Condition Score (1-5)	0.651*	0.033	0.581*	0.428*
Age (years)	0.90*	0.691*	0.163	0.832*

*P≤0.01

where by BCS1 is a dummy variable (yes/no, i.e. 1/0) for a BCS 1 between ≥2.5-<4, and BCS 2 is a dummy variable (yes/no, i.e. 1/0) for a BCS ≥4-≤5. The variable SH had to be omitted from the multiple linear regression equations due to its co-linearity with HG and BL.

The accuracy of functions to be used for the prediction of body weight from morphometric measurements is of economic relevance for livestock producers and buyers, in order to adjust specific management decisions (feeding, health, and breeding)for optimum production, and for value-based trading. There is only one major study published on BW estimation in Nili-Ravi buffaloes (Khan *et al.*, 1978; Table 1). In contrast to the present study, the animals used for that study originated from different production systems - research stations as well as private farms; in addition, no records of age were available for these animals. The mean values of BL and SH in the present study are higher than those reported by Khan *et al.* (1978) for Nili-Ravi buffaloes, while the mean value of HG in the present study is somewhat lower than that reported by Tahir *et al*. (2000). These differences might be attributed to age and nutritional factors.

The present correlation coefficients between body measurements (HG, BL and SH) and BW for all three age groups are higher than those reported by Khan *et al.* (1978), which might have been due to differences in management as well as in animal numbers (211 used here *versus* 350 used by Khan *et al.*,1978). Among the various morphometric variables, HG was most closely correlated with BW in all three age groups, followed by BL, which agrees with previous findings (Singh *et al*., 1994; Abdelhadi and Babiker, 2009). A positive correlation was also recorded between BW and the age of buffaloes. Indeed, BW, BL and all other body measurements increase as an animal ages (Naz and Ahmad, 2006). According to Sethi *et al*. (1996), in buffaloes up to 24 months of age, body height is the most significant variable for predicting BW, whereas in heifers >24 months and in adult buffaloes HG is the most significant variable. Similarly, Satyanarayana and Murty (1981) reported chest depth to be the best predictor of BW. Body condition score was positively and significantly correlated with BW of Nili-Ravi buffaloes in the present study, which agrees with various authors (Msangi *et al*., 1999; Nesamvuni *et al*., 2000; Abdelhadi and Babiker, 2009). According to Yildiz *et al*. (2011), BCS accounted for 16% of the variation in BW, and the correlation coefficient between BW and BCS in cows was positive (r=0.40). Similar correlations were reported by Nesamvuni *et al*. (2000) for Nguni-type cattle (0.47), Northcuttz *et al*. (1992) for

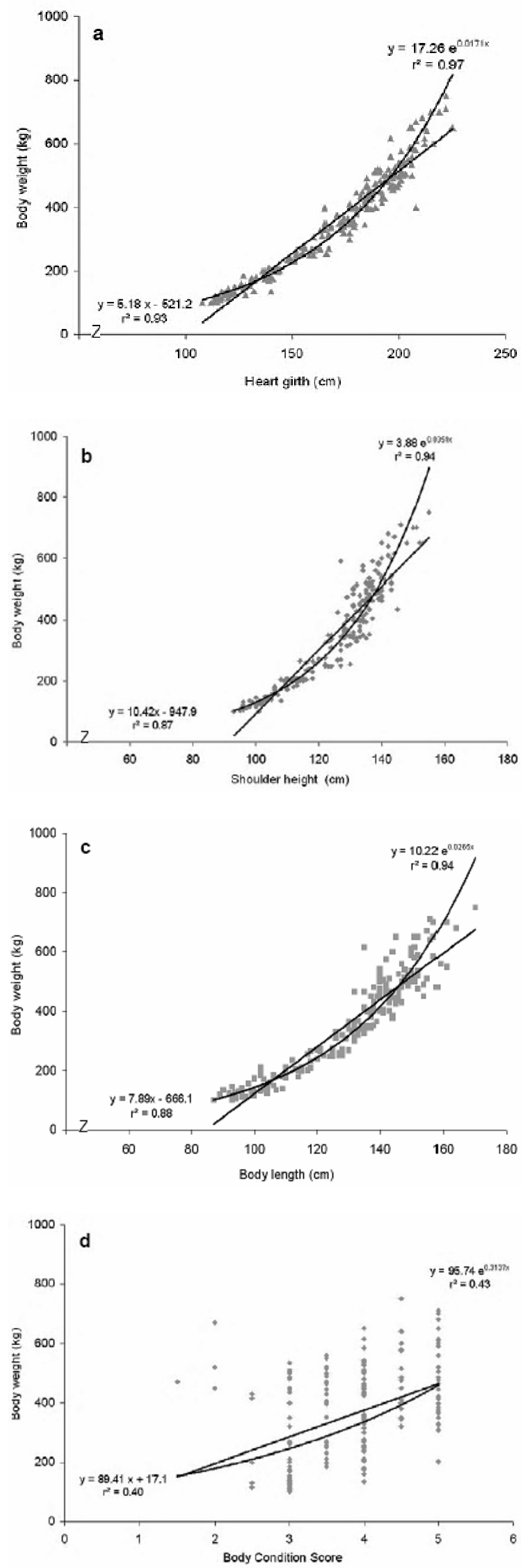

Fig. 1: Simple linear and simple polynomial regression equations between body weight (y) and the independent (x) variables (a) heart girth, (b) shoulder height; (c) body length, and (d) body condition score.

Table 3: Body weight and morphometric measures (Means±SD) for different age groups of Nili-Ravi buffaloes

Variables	G1 (1–3 yrs)	G2 (>3-8 yrs)	G3 (>8 yrs)	Total population	P≤
No. of animals	84	94	33	211	
Body weight (kg)	192.8±61.8[a]	448.4±100.6[a,b]	529.5±67.5[b]	359.3±160.9	0.001
Heart girth (cm)	139.1±17.2[a]	187.7±13.9[a,b]	200.3±8.7[b]	169.9±30.1	0.001
Body length (cm)	109.8±12.2[a]	141.5±8.4[a,b]	147.8±5.9[b]	129.9±19.2	0.001
Shoulder height (cm)	110.6±10.1[a]	134.4±6.5[b]	137.5±4.9[b]	125.4±14.5	0.001
Body Condition Score (1-5)	3.5±0.6[a]	4.1±0.8[b]	4.0±0.8[b]	3.8±0.8	0.001

Means with different letters within rows differ significantly (P<0.05).

Table 4: Multiple regression equations for three age groups of Nili-Ravi buffaloes between the dependent variable body weight (Y, kg) and independent morphometric body measures as well as body condition score (BCS)

Parameters of the regression equations		Tolerance[#]	VIF[#]	Partial R^2	R^2
Group 1 (1–3 yrs; n=84)					
Constant	-334.1				
Heart girth (cm)	+2.4	0.12	8.3	0.78	
Body length (cm)	+0.1	0.12	8.3	0.24	
BCS1* (dummy)	-9.8	0.49	2.1	0.08	
BCS2* (dummy)	-0.2	0.50	2.0	0.22	
Y = -334.1 + 2.4 HG + 0.1 BL - 9.8 BCS1 - 0.2 BCS2					0.95
Group 2 (>3–8 yrs; n=94)					
Constant	-1142.5				
Heart girth (cm)	+3.9	0.46	2.9	0.76	
Body length (cm)	+2.6	0.45	2.2	0.51	
BCS1 (dummy)	-46.9	0.15	6.5	-0.03	
BCS2 (dummy)	-27.9	0.15	6.5	0.07	
Y = -1142.5 + 3.9 HG + 2.6 BL - 46.9 BCS1- 27.9 BCS2					0.86
Group 3 (>8 yrs; n=33)					
Constant	-1229.6				
Heart girth (cm)	+2.7	0.44	2.3	0.69	
Body length (cm)	+1.0	0.74	1.4	0.49	
BCS1 (dummy)	-57.0	0.17	6	-0.03	
BCS2 (dummy)	-31.0	0.13	7.9	0.19	
Y= -1229.6 + 2.7 HG + 1.0 BL - 57.0 BCS1 - 31.0 BCS2					0.83

* BCS1 is a dummy variable (yes/no, i.e. 1/0) for a BCS between ≥2.5 - <4 and BCS = is a dummy variable (yes/no, i.e. 1/0) for a BCS ≥ 4 - ≤5; [#] Tolerance and VIF: *variance* inflation factor indicating co-linearity between predictor variables' indicators.

Angus (0.48) and Berry *et al*. (2001) for Irish Holstein-Friesian cows (0.49). However, in our multiple linear regression equations, we did not use BCS as such but a combination of two dummies for a relatively wide range of BW each: BCS1 covers animals of good condition (BCS ≥2.5-<4) and BCS2 points to animals of very good or even fat body condition (BCS ≥4-≤5). The combination of these two dummies in the equations covers all stages of body condition, namely skinny to lean animals (BCS <2.5: BCS1=BCS2=0), animals of normal to good condition (BCS1=1, BCS2=0), and fat animals (BCS1=0, BCS2=1), and a small under- or over-estimation of the BCS by 0.5 points would therefore in most cases not have affected the precision of BW calculation.

The analysis of regression equations given in Table 1 and our newly established equations for the three groups reveals that the correlation coefficient of the prediction equation is neither related to the number of animals on which equations are based nor on the number of different morphometric variables included in the equation. This is also seen when comparing the multiple regression equation for the first and the second age group (G1, G2; Table 4): the number of animals involved is similar (G2 > G1) and the number of independent variables is identical.

However, R^2 is considerably higher for equation G1 than that for equation G2, pointing to the fact that an increasing variation in body condition reduces the accuracy of BW estimation as animals become older and get heavier. A differentiation of age groups and use of specific equations for these seems therefore justified and even advisable.

Conclusion: We found a close correlation between the body weight of Nili-Ravi buffaloes and the morphometric variables including heart girth and body length as well as body condition score. Although BC scoring is not very common with respect to buffalo husbandry in Pakistan, our results suggest that this tool should be divulged to help producers in taking managerial decisions. After some hours of training by government extension services or NGOs on how to do BC scoring and measure HG and BL, small- and medium-scale commercial buffalo farmers lacking weigh scales should be able to easily and with satisfactory accuracy estimate the BW of their animals. Since our equations do not use the BCS itself but a combination of two dummies for a relatively wide range of body conditions each, a small misjudgment of the BCS will not affect the precision of BW calculation. However, in buffaloes aged ≤8 years simple measurement of heart girth and use of age-specific simple linear regression equations [Eq.1, Eq. 2] might already suffice a farmer for BW assessment of acceptable accuracy.

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