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Short communication

Use of heart girth to predict body weight of working oxen in the Ethiopian highlands

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Abstract

Few studies have been conducted in sub-Saharan Africa where multiple recordings of heart girth and body weight were made for the same cattle population. In this study, monthly measurements were taken of working oxen on 24 smallholder farms in the Ethiopian highlands for 1 year. The overall yearly mean body weight of oxen across working and nonworking periods was 281±37 kg. No significant differences in mean monthly body weights were observed, except for December and January compared to August (297±36 and 296±37, and 271±35 kg, respectively, $P<0.05$) and December versus April 272±35 kg ($P<0.05$). Simple linear regression equations derived from body weight and heart girth measurements were significantly different between months. Nevertheless, separate monthly equations and a single equation for the year explained variation in body weight about the same. The monthly equations predicted 83 to 95% of oxen weights to within ±10% of weighbridge values, while the equation for the entire year predicted 87%. The R^2 values for the monthly equations ranged from 0.63 to 0.87 and the R^2 value for the entire year was 0.75. The single equation for the year predicted body weight of oxen as a group to within ±27 kg of mean monthly weighbridge values, whereas for a single animal the predicted body weight was ±37 kg of the actual weight (C.I. 95%). The single equation can be used to monitor mean body weight of the oxen population equally well across working and nonworking periods of the year.

Keywords: Body weight; Heart girth; Oxen; Draught; Ethiopia

1. Introduction

Numerous studies have been conducted in sub-Saharan Africa to develop methods of estimating live body weight of cattle using formulae derived from body measurements. A majority of these studies were carried out on government research stations or private ranches with cattle populations comprised primarily of *Bos indicus* or zebu type breeds of mixed ages and sexes, although some included *Bos taurus* or European type breeds, as well as crosses between the two types (Table 1). In all the countries where the studies were done, mainly oxen, but also intact males, and in some areas cows, play an important role as draught animals, primarily for ploughing, but also for secondary cultivation (i.e.,

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Table 1
Geographical distribution of studies carried out in sub-Saharan Africa to estimate live weight of cattle using formulae derived from body measurements

Country	Breed/type[a]	Management[b]	Source
Cameroon	Peul (Adamaoua)	RS	Dumas and Lhoste (1966)
Congo	Alur, Bahima (Ankolé)	T	Maricz (1961)
Côte-d'Ivoire	Baoulé, N'Dama, Baoulé × N'Dama	RS, T	Poivey et al. (1980)
Ethiopia	Horro, Barca, Boran and exotic crosses[c]	RS, T	Taylor and Galal (1980)
Ethiopa	Abyssinian Short-horned zebu	T	Goe et al. (this work)
Gambia	N'Dama	T	Spencer and Eckert (1988)
Kenya	East African Short-horned zebu[d] and crosses[e]	R, T	Young (1972)
Kenya	East African Short-horned zebu and crosses[f]	T	Semenye (1979)
Kenya	East African Short-horned zebu	T	Sandford et al. (1983)
Malawi	Malawi zebu, Malawi zebu × Friesian	RS	Spurling (1974)
Malawi	Malawi zebu	RS	Mwambaghi (1977)
Mali	Maure, Peul (White Fulani)	RS	ILCA (1978)
Nigeria	White Fulani	RS	Gates (1948)
Nigeria	White Fulani	RS	Ross (1958a)
Nigeria	White Fulani, Sokoto (Gudali), N'Dama	RS	Buvanendran et al. (1980)
Nigeria	Bunaji, Sokoto (Gudali)	RS	Buvanendran and Olorunju (1985)
Nigeria	Boran, Muturu, N'Dama	RS	Nwosu et al. (1985)
Rwanda	Ankolé	RS	Compere (1964)
Senegal	Gobra (Senegal Fulani)	RS	IEMVT (1978)
Senegal	N'Dama	RS	Fall et al. (1982)
Sierra Leone	N'Dama	T	Thomas and Starkey (1983)
South Africa	Afrikander, Angus, Hereford, Sussex	RS	Bonsma and Neser (1951)
South Africa	Ayrshire, Guernsey, Jersey	RS	Fourie (1959)
Sudan	N'Dama	RS	Pagot and Delainer (1959)
Sudan	Kenana (Sudan zebu)	RS	Pollott and Ahmed (1979,1980)
Sudan	Baggara zebu	T	Wilson and Henrici (1979)
Swaziland	Nguni	T	Ogwang and Xaba (1996)
Tanzania	Tanganyika zebu and Hereford crosses	RS	Hutchison (1959)
Uganda	Teso zebu (Nkedi)	RS	Manning and Williams (1950)
Uganda	Teso zebu (Nkedi)	R, RS	Ross (1958b)
Uganda	Ankolé, Teso zebu (Nkedi)	RS	Thornton (1960)

[a] According to Mason and Maule (1960) and Mason (1969).
[b] T, Traditional (includes village, smallholder, pastoral, etc.); R, private or government ranch; RS, research station or stock farm.
[c] F_1 with Friesian, Simmental, and Jersey.
[d] Masai, Taita, Boran.
[e] Masai × Sahiwal.
[f] Boran and Sahiwal bulls.

harrowing, planting, weeding, harvesting) and other activities (e.g., carting, logging, water-lifting) (Starkey, 1988; Starkey et al., 1991). However, there is little information available on estimating live weight of working oxen using body measurements. The use of heart (chest) girth to predict body weight of castrated males is discussed in several studies (Manning and Williams, 1950; Compere, 1964; Dumas and Lhoste, 1966; Young, 1972; Mwambaghi, 1977; Poivey et al., 1980), but no information is given whether the animals were used for draught. Ogwang and Xaba (1996) employed a pre-calibrated commercial weighband to estimate body weight of working oxen over a 6-month period, however, no prediction equation was given. Taylor and Galal (1980) recorded heart girth and body weight of oxen, but the prediction equation was derived from only a single set of measurements. Multiple recordings of heart girth and body weight of off-station cattle populations are limited (Wilson and Henrici, 1979; Sandford et al., 1983). A search of the Agricole, AGRIS and CAB International databases covering the last 20-year period indicates a continued void in the literature of such information. Thus, the work reported here, although based on data collected in the 1980s as part of a larger study, remains unique because it monitored changes in body weight and heart girth of oxen on smallholder farms across working and nonworking periods for 12 consecutive months. The findings presented remain valid and are applicable to oxen used in the crop–livestock production system found throughout many parts of the Ethiopian highlands today. The paper also serves as a comprehensive literature review on heart girth studies carried out in sub-Saharan Africa.

2. Materials and methods

2.1. Study area

The study was carried out on 24 smallholder farms in the Debre Birhan area (latitude 9° 40° North and longitude 39° 32° East, 2800 m above sea level) located 130 km northeast of Addis Ababa in the Shewa Plateau region of the Ethiopian highlands. A traditional mixed crop–livestock system of farming is practiced (Gryseels and Anderson, 1983). Cattle, mainly Abyssinian Short-horned zebu (Alberro and Haile Mariam, 1982a,b), are raised as a source of offspring for draught power (primarily oxen) and for milk and manure. A traditional single-tined ard (*maresha*) pulled by a pair of oxen with a wooden shoulder yoke is used for tillage of plots, the majority of which are stone-covered and located on slopes (Goe, 1990, 1999).

2.2. Working and nonworking periods

Land preparation for the minor and major cropping seasons is carried out from mid-January through March or early April, and from the beginning of May through July or early August, respectively. Ploughing of drainage furrows across plots to control water runoff or initial ploughing of long term fallow (> 5 yr) plots is done during September and October. Ploughing usually starts between 08:00 and 09:00 and ends between 12:30 and 14:00 when a break of about an hour is taken to feed and water the oxen or allow them to graze. If work is resumed or begins in the afternoon it usually ends around 17:00 so animals can be watered before the evening feeding. Oxen are used for ploughing for an average of 5.5 h per day (range 3 to 7.5 h) and are generally not worked for more than 2 to 3 days consecutively per week. All tillage activities total between 45 to 50 days a year. Oxen and equines are used for threshing of crops 10 to 15 days per year (5 to 7 h per day), usually from mid-December through February.

2.3. Feed resources

On-farm feed resources for oxen include hay, straw from crop residues (mainly barley, wheat and horse bean), grazing of crop stubble and natural pastures, and green feed from crop weedings. Oxen are usually fed three times on working days and, if time permits, allowed to graze. On nonworking days, including weekends, oxen are fed in the morning before being taken for grazing and then again in the evening. At the start of the major cropping season, beginning at the end of April or early May, hay is given on working days and straw on nonworking days. As the cropping season progresses and hay supplies began to dwindle, farmers often feed a mixture of hay and straw on working days (e.g., straw in the morning, hay at noon, and straw again in the evening). Depending on the amount of stored feed supplies remaining in mid-July, there may only be straw left for feeding on working days, and grazing on nonworking days. If straw supplies become exhausted then, regardless whether it is a working or nonworking day, oxen will be totally maintained by grazing on natural pastures and crop stubble of minor season plots. From the end of August through mid-December stored feed supplies are usually depleted and animals are only grazed. However, the quality of natural pastures improves during this period following the major rains. From January through March, oxen have access to crop residues at the threshing areas. Animals are normally watered once per day. After the evening feeding, animals are kraaled for the night without access to feed or water.

2.4. Measurements

Twenty-four pairs of oxen (each pair belonging to a different farmer) were ear-tagged and age estimated according to dentition (Kikule, 1953). Heart girth and corresponding body weight measurements of animals were recorded monthly from October 1982 through September 1983. Measurements were taken on the second or third Sunday of each month between 07:00 and 08:00 before animals were fed, watered or allowed to graze. Taking measurements at this time ensured that at least 36 h would have passed since the most recent working day, resulting in all oxen being on the same daily feeding–grazing schedule and receiving similar feedstuffs. Differences in body weight between animals due to gut fill were considered to be minimized for each monthly weighing, although it was recognized that due to variability in the type, quality, and quantity of feed resources during the year rumino-reticulum contents would not necessarily remain constant across months. Since oxen did not have access to water or feed during the 12 to 14 h prior to weighing, variation in body weight, except for real differences between animals, was reduced (Hughes and Harker, 1950; Hutchison, 1959; Yates and Larkin, 1965).

Heart girth was measured while animals were standing in a crush before weighing. A plastic tape marked in centimeters (cm) was drawn around each animal directly behind the front legs and the base of the hump. Oxen were weighed using a mobile weighbridge (Bauman, Type 2010/B). Body weight was recorded to the nearest kilogram (kg). Heart girth measurements and weighbridge readings were taken by the same individuals throughout the study period.

2.5. Statistical analysis

Descriptive statistics and regression analysis of the data were carried out using a general linear models (GLM) procedure (SAS Institute, 1989). The regression relationship between body weight and heart girth were examined for each month. Analysis of covariance methods were used to test for homogeneity of slopes and intercepts across months. Monthly mean body weight and heart girth measurements were compared using the Tukey HSD-procedure (Kuehl, 1994).

3. Results

Unexpected changes in farmer schedules and sickness or replacement of animals resulted in an average of 45 ± 2.8 oxen being weighed and taped monthly. A total of 15 oxen were replaced by farmers during the year. The mean ages of animals present for the duration of the study and those replaced were similar (8.0 ± 1.9 yr and 8.2 ± 1.9 yr, respectively). The mean body weight of oxen over the 12-month period was 281 ± 37 kg. The relationship between monthly mean weights and average number of days oxen were worked per corresponding month is depicted in Fig. 1. Animals were heaviest from November through January, averaging 295 ± 37 kg. There were no significant differences in mean weights across months, except for December and January compared to August (297 ± 36 and 296 ± 37, and 271 ± 35 kg, respectively, $P < 0.05$) and December versus April 272 ± 35 kg ($P < 0.05$). Monthly mean heart girth measurements showed little variation, ranging from 152 ± 7 to 155 ± 8 cm.

Simple linear regression equations derived from body weight and heart girth measurements were calculated for each month and for the complete year (Table 2). Tests for homogeneity of regression slopes showed no significant differences in slopes among months ($P = 0.279$). There were significant differences in intercepts by month of sampling ($P < 0.001$). The coefficients of determination (R^2) for separate monthly regression equations ranged from 0.63 in October to 0.87 in January. The R^2 for the regression equation for the complete year was 0.75. The single equation for the year and the separate monthly equations give similar results across working and nonworking periods. The single equation predicted 87% of the oxen weights to within $\pm 10\%$ of the weighbridge values, whereas the separate monthly equations predicted 83 to 95%. The single equation for the year predicted best in January and July, with 95% of all oxen weights estimated to within $\pm 10\%$ of weighbridge values. The separate

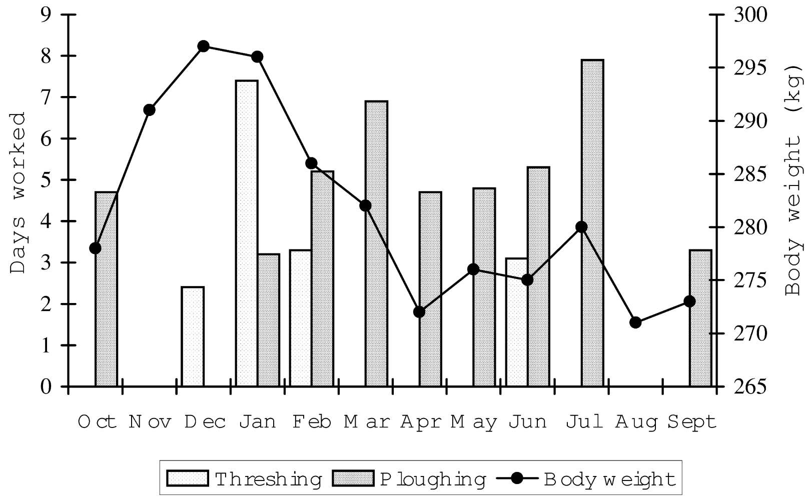

Fig. 1. Variation in monthly mean oxen weights across working and nonworking periods of the year (1982–1983) in the Debre Birhan area of the Ethiopian highlands.

Table 2
Regression equations derived from body weight and heart girth measurements of oxen on smallholder farms in the Debre Birhan area of the Ethiopian highlands

Month	n	Mean body weight (kg)	Mean heart girth (cm)	Equation[a,b]	R^2	% Within ±10% of weighbridge
October	46	277.8	153.5	$y = 3.37x - 238.6$	0.66	87
November	41	290.6	154.1	$y = 3.85x - 302.1$	0.63	88
December	47	297.5	154.7	$y = 3.81x - 293.1$	0.77	91
January	44	296.1	155.2	$y = 4.41x - 387.8$	0.87	95
February	48	286.4	153.6	$y = 4.67x - 430.7$	0.83	92
March	48	281.7	152.9	$y = 4.51x - 408.0$	0.79	83
April	47	272.5	152.0	$y = 4.17x - 361.9$	0.75	87
May	43	276.1	153.5	$y = 4.40x - 398.6$	0.81	88
June	42	275.0	153.0	$y = 4.19x - 365.8$	0.82	90
July	40	279.6	154.1	$y = 4.41x - 400.1$	0.79	95
August	47	270.7	152.5	$y = 4.22x - 372.1$	0.72	85
September	46	273.1	154.2	$y = 4.15x - 366.6$	0.75	85
Overall	539	281.4	153.6	$y = 4.21x - 364.9$	0.75	87

[a] Where x = heart girth in cm and y = predicted weight in kg.
[b] Significance level for all equations $P < 0.001$.

equations estimated that a 1 cm change in heart girth would result in a weight change of 3.4 to 4.7 kg. The overall equation estimated a 4.2 kg change in weight for each 1 cm change in heart girth. The 95% prediction interval for the weight of an individual ox has a width of approximately ±35 kg over the entire range of data.

4. Discussion

The findings indicate that body weight changes of mature working oxen in the Debre Birhan area are minimal across working and nonworking periods of the year. The extent to which the observed increases in monthly mean oxen weights, particularly from the end of October through January, were due to actual gain in body tissue or influenced by gut fill cannot be determined from the data collected in this study alone. Such an evaluation would require additional measurements (e.g., employing rumen-fistulated animals or the use of tritiated water to estimate fat reserves). Since little ploughing was carried out from late October to February and oxen had access to high fibre crop residues during the threshing season, it is possible that some gain in body tissue could have occurred. Improved quality of natural pastures following the major rains in July through September may also have contributed to the weight increases observed for October through January. However, because the length of time between feeding and weighing of oxen was fairly constant throughout the study, it must be suspected that rumino-reticulum contents for these 4 months might have been greater than for the rest of the year, thereby also influencing the increases in body weight observed. Studies have shown that the wet weight of rumino-reticulum contents of zebu type cattle in East Africa can equal 15% or more of body weight, depending on diet and season of the year (Hungate et al., 1959; Reed, 1983).

Heart girth measurements did not accurately reflect real differences in oxen body weights between months. Separate monthly regression equations tended to predict body weight most accurately when oxen were heaviest (i.e., December through February). As heart girth reflects animal frame size, it is possible that during this period oxen were in more uniform condition and, therefore, heart girth measurement was more accurate. However, exceptions to this can be seen for June and July when monthly mean weights were slightly below the yearly mean. Why this occurred is not clear, although possible reasons could include changes in the numbers of oxen brought for weighing each month, animals leaving and entering the group through replacement and(or) marked changes in weights of some oxen due to actual gain or gut fill. There was no bias discovered in the ability of the regression equations to predict body weight due to replacement animals.

It is known that curvilinear functions can be used in predicting animal weights over a complete growing period, provided that groups upon which the function is based are sufficiently well represented and not comprised of animals of different condition (Johansson and Hildeman, 1954). However, where there is large variation in breed, age, sex and(or) plane of nutrition across a particular population, the calculation of separate linear regression equations for groups in which these differences are minimized will usually provide the most accurate estimates of body weight (Tulloch and Maritz, 1964; Gravir, 1967; Young, 1972; Buvanendran et al., 1980; Poivey et al., 1980). In this study here, higher order polynomial equations were examined, but found not to be statistically significant. This is not surprising because the animals were mature and not growing. Similarly, log transformation of the data was unnecessary because animals had a narrow range of ages (Young, 1972; Buvanendran et al., 1980). Moreover, transformation of data requires additional mathematical calculations which further complicates the use of heart girth to provide a simple way of predicting body weight to within a known confidence interval, which is the overall purpose of the applying the technique in the field. Likewise, no attempt was made to include other body measurements [e.g., height at withers, hip height and(or) various forms of body length] in the equations. Other studies have demonstrated that such additional measurements provide little appreciable increase in accuracy of body weight estimates over equations which used heart girth alone. Even in cases where improvements were found to be significant, actual reduction in the error of live weight estimates was small (Johansson and Hildeman, 1954; Ahuja et al., 1965; Buvanendran et al., 1980; Qureshi et al., 1980; Rathi et al., 1980).

Overall, the equations developed for the complete year and for separate months predicted 85% or more of the oxen weights to within $\pm 10\%$ of the weighbridge values. Heart girth accounted for an average of 75% of the variation in oxen body weight. These figures are comparable to results given in the studies cited in Table 1. The ability of the regression equation for the year to explain variation in body weight nearly as well as the individual monthly equations may have implications concerning the findings of Taylor and Galal (1980) for Horro oxen in Ethiopia. A regression equation derived from body weight and heart girth measurements taken in August–September predicts about the same percentage

Table 3
Comparison of regression equations derived from body weight and heart girth measurements of Abyssinian Short-horned and Horro oxen

Breed	Month	n	Mean weight (kg)	Mean heart girth (cm)	Equation[a]	R^2	% within ±10% of weighbridge
Abyssinian Short-horned[b]	August	48	269	152	$y = 4.11x - 354$	0.65	85
Abyssinian Short-horned[b]	September	46	273	154	$y = 4.15x - 367$	0.75	85
Horro[c]	August/September	102	265	151	$y = 4.17x - 363$	0.87	89

[a] Where y = weight (kg) and x = heart girth (cm).
[b] Present study.
[c] Data from Taylor and Galal (1980).

of animal weights to within ±10% of the weighbridge values as the two respective monthly equations from this study (Table 3). The similarities between the three equations and the mean values for heart girth and body weight for the two studies suggests that a characteristic heart girth to body weight relationship exists among the Sanga type zebu breeds of oxen in the Ethiopian highlands. Whether the regression equations (complete year or monthly) developed in the present study could be used to estimate weights of other types of Abyssinian zebu oxen (i.e., Jigiga or Small zebu and Jem Jem or Black zebu) which are similar in size and weight to Short-horned zebu (Alberro and Haile Mariam, 1982a,b) would require further investigation.

5. Conclusions

Oxen continue to provide the main source of power for tillage on smallholder farms in the Ethiopian highlands. It is recommended that the prediction equation for the complete year be used to estimate oxen weights on farms around Debre Birhan and in the surrounding areas. The equation will be most accurate when used to estimate the mean body weight of a particular population of oxen (e.g., periodic village level or market surveys or vaccination campaigns), rather than the weight of an individual animal. It is important that the purpose for which oxen weights are required is identified. If extremely accurate results are required (e.g., draught force or feed intake expressed as a percentage of body weight) then a weighbridge should be used. The most optimum and efficient system of acquiring information on body weight of oxen may involve the use of heart girth in conjunction with a weighbridge. Heart girth could be used to obtain estimates of body weight during periods of the year when animal management is consistent and feed resources relatively constant, whereas during the dry season, a weighbridge would provide the most accurate method of assessing changes in oxen weights. In situations where only general information is required regarding overall animal condition and actual body weights are not necessary (e.g., monitoring animal performance on natural pasture or rangelands), then consideration might be given to the use of body condition scoring (Nicholson and Butterworth, 1986; Nicholson and Sayers, 1987). However, as with heart girth, changes in body weight may not be accurately correlated with indicies represented by body condition scoring (Osuji and Capper, 1992).

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