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GIRAFFE WEIGHT ESTIMATION USING DISSECTED LEG WEIGHT AND BODY MEASUREMENTS

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Abstract: Data from 44 adult giraffes (*Giraffa camelopardalis*) showed that leg weight as a percentage of body weight is sufficiently constant to provide regression equations useful for estimating body or carcass weight. Data from 53 giraffes of various ages show that reliable estimates of body weight can be made from linear body measurements, regardless of sex or age. The best for field use are linear regressions between body weight and chest girth; however, shoulder height is usually the only measurement obtained from predator kills and this can also be used. Measures of the volume of the animals such as length $\times$ girth^2 and log transformations give superior correlations.

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A high correlation between dissected leg weight and liveweight in Boran steers (*Bos indicus*) was reported by Ledger (1965) and used for predicting liveweight in cattle and 8 species of wild African ungulates (Smith and Ledger 1965). This relationship was also found to hold good for African elephants (*Loxodonta africana*) by Laws et al. (1967) and was regularly used for estimating body weight of this species (Laws et al. 1975).

Relationships between standard body measurements and weight for domestic and wild African animals have also been investigated (Talbot and McCulloch 1965, McCulloch and Talbot 1965, Freeman and King 1969, Hanks 1972, Bertram 1975, Howells and Hanks 1975, Smuts 1975) and expressions have been derived for weight estimations.

These methods find ready application in estimating predator or scavenger consumption, studies of meat production, nutrition, growth rates, condition, and estimates of weight for drug dosage rates and the transport of live animals. The purpose of this study was to investigate some of these relationships for the giraffe and to find reliable criteria for weight estimation applicable to live and butchered animals as well as animals killed by lions (*Panthera leo*).

Appreciation is extended to the owners of the Timbavati, Sandringham, and Buffelshoek nature reserves for making the material available for this study. Professor J. D. Skinner is also thanked for his help as are the University of Pretoria and the Council for Scientific and Industrial Research, South Africa, for financial assistance.

MATERIAL AND METHODS

Material was obtained from culling and research programmes in the woodland/savanna regions of the eastern Transvaal Lowveld of South Africa. Immediately after shooting and bleeding the giraffes were measured as described below, then dissected and weighed in pieces as described by Hall-Martin et al. (1977). As this was done in the field, taking 2–3 hours, it was not possible to make allowance for weight loss due to evaporation nor for blood and body fluids lost during handling. The sum of the weights of all other body components are termed "body weight." The term "foreleg" as used here accords with the definition of Ledger (1963), the "hindleg" is as meant by Laws et al. (1967), while "carcass" is the body less skin, head, tail, feet, viscera, kidneys, and kidney fat (Hall-Martin et al. 1977). A regularly calibrated Salter spring

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Table 1. Weights of giraffe hindlegs, forelegs and stomachs (including contents) as percentages of body weight.

Sex	*N*	Age range[a] (years)	Body weight kg (range)	Hindleg as percent of body weight ($\bar{x} \pm$ SD)	Foreleg as percent of body weight ($\bar{x} \pm$ SD)	Stomach plus contents as percent of body weight ($\bar{x} \pm$ SD)	Stomach plus contents as percent of body weight (range)
Male	19	8–23	849–1,395	8.8 ± 0.42	8.0 ± 0.36	11.5 ± 1.3	8.5–13.6
Female	25	6–20	636– 950	8.9 ± 0.41	7.4 ± 0.39	13.9 ± 2.8	8.2–20.7

[a] Age determination as described by Hall-Martin (1976).

balance with a capacity of 200 kg was used. Fifty-seven giraffes were weighed and linear measurements of 53 of these were recorded. Linear measurements made on animals in lateral recumbency were total body length (L) which included head and tail, shoulder height (H) measured in a straight line from the level of the hoof to the top of the withers, and chest girth (G) taken just caudal to the front legs. Standard correlation and regression procedures (Simpson et al. 1960, Sokal and Rohlf 1969) were used to measure the degree of correlation between variables, to provide predictive functions and to judge the accuracy with which one variable may be predicted from another. For paired comparisons the Students *t*-test (Simpson et al. 1960) was used.

RESULTS AND DISCUSSION

Weight Estimation Using Dissected Leg Weights

Body weights and dissected leg weights of 19 adult male and 25 adult female giraffes were examined. There was a reasonably wide range of body weights due to age, sex, variations in stomach fill and seasonal influences (Hall-Martin et al. 1977); giraffe lose condition as the quality of their diet declines during the dry season (Hall-Martin 1975). Nevertheless, the leg weights as percentages of body weight showed little variation (Table 1). However, there was a significant decrease in percentage hindleg with age in the males ($P < 0.01$) but no such difference in the foreleg or among the females. This difference has been explained by Hall-Martin et al. (1977) as being due, in part, to the disproportionate increase in size of the neck in the older males.

It was therefore appropriate to calculate regression equations of leg weights on body weights and carcass weights for males and females separately (Fig. 1). These equations, together with correlation coefficients are presented in Table 2. The mean hindleg or foreleg weight was used in each case as it was shown that there were no statistically

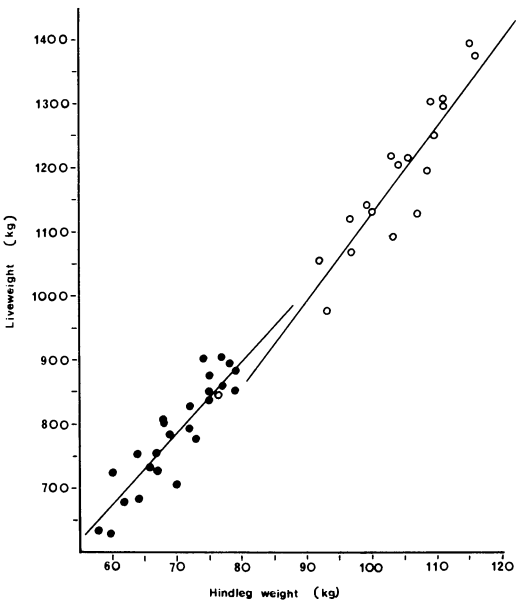

Fig. 1. Liveweight/hindleg weight relationships in adult giraffes (dots = females, circles = males). Separate regression lines for males and females are shown.

Table 2. Equations for estimating weight of giraffe from the eastern Transvaal Lowveld. Body weight (W), carcass weight (C), hindleg weight (H) and foreleg weight (F) in kilograms.

	N	Regression equation	r^a
Hindleg/body weight			
Adult female	25	W = 11.80 H − 39.1	0.905
Adult male	19	W = 13.42 H − 209.3	0.924
Foreleg/body weight			
Adult female	25	W = 12.21 F + 78.9	0.876
Adult male	19	W = 11.44 F + 103.5	0.925
Hindleg/carcass weight			
Adult female	25	C = 7.15 H − 53.95	0.959
Adult male	19	C = 8.50 H − 149.61	0.932
Foreleg/carcass weight			
Adult female	25	C = 7.72 F − 1.01	0.974
Adult male	19	C = 10.66 F + 44.22	0.967
Hindleg/body weight less reproductive tract			
Adult female	25	W = 10.86 H + 9.38	0.889
Foreleg/body weight less reproductive tract			
Adult female	25	W = 11.16 F + 122.17	0.859

[a] All *r* significant ($P < 0.001$).

significant weight differences between left and right sides (Students *t*-test). All correlation coefficients of the prediction equations were found to be highly significant ($P < 0.001$) indicating that accurate estimations of body weight or dressed carcass weight can be obtained if a hindleg (Fig. 1) or foreleg weight is known.

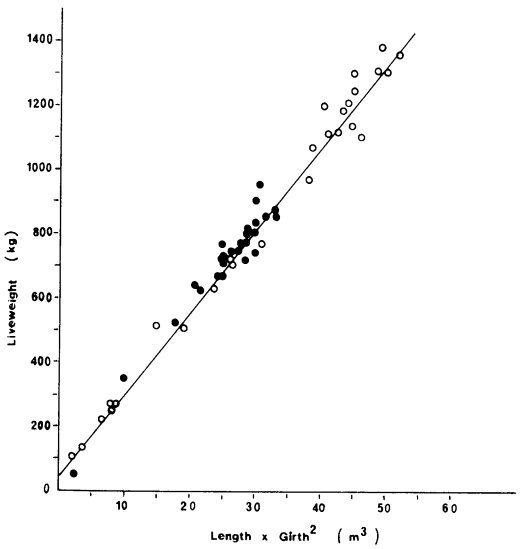

Fig. 2. Relationship of liveweight to length × girth² in giraffes of various ages (dots = females, circles = males). Regression line, for the relationship irrespective of sex, is shown.

The weight of the reproductive tract and its contents in the pregnant giraffe female can be as much as 169 kg, or 18.8 percent of the body weight (Hall-Martin 1975). Regression equations were therefore calculated for females with the weight of the gravid tract subtracted from the body weight but this yielded poorer correlations (Table 2) than when the tract was included. This is very likely due to the compensating effect of decreased stomach fill during advanced pregnancy in giraffe females (Hall-Martin 1975), a factor not noted by Smith and Ledger (1965) who subtracted the uterine contents weight from the liveweight of female animals in their study.

Smith and Ledger (1965) found that the relationship between leg weight and liveweight was similar for all ages, sexes and degrees of fatness in the species they examined with the single exception of the water-

Table 3. Relations between body weight (W) in kg, girth (G) in cm, shoulder height (S) in cm and total length (L) in cm for giraffe from the eastern Transvaal Lowveld.

N	Sex	Relationship	*r*[a]
27	Male	W = 6.989 G − 904	0.975
26	Female	W = 5.500 G − 615	0.965
53	Both	W = 6.748 G − 881	0.963
27	Male	W = 6.752 S − 1,051	0.973
26	Female	W = 5.659 S − 783	0.932
53	Both	W = 6.604 S − 1,022	0.965
27	Male	W = 4.223 L − 964	0.966
26	Female	W = 3.251 L − 635	0.938
53	Both	W = 4.061 L − 934	0.952
27	Male[b]	W = 26.117 LG^2 + 33.945	0.993
26	Female[b]	W = 25.400 LG^2 + 66.109	0.977
53	Both[b]	W = 25.902 LG^2 + 45.758	0.990

[a] All *r* values significant ($P < 0.001$).
[b] Length × Girth^2 in m^3.

buck (*Kobus defassa*). In that species, as in the giraffe, hindleg percentage decreased with age in males. Conversely, in the African elephant there is a decline in the percentage of hindleg with increasing body size in females and young males and an increase in adult males (Laws et al. 1967). In giraffe little variation in these relationships can be ascribed to fatness, as carcass fat deposits show little fluctuation (Hall-Martin et al. 1977).

Weight Estimation from Body Measurements

Body weight and body measurements were available for 27 male and 26 female giraffes of various ages. Regression equations for the relationships confirm a high degree of correlation between weights and the linear measurements (Table 3). Data for males and females were handled separately and the equations compared. The between sex regressions were all significantly different (girth—$P < 0.001$, height—$P < 0.05$, length—$P < 0.001$). The data were, however, pooled and further regression coefficients calculated as it is often difficult or impossible to establish the sex of young animals killed and partly eaten by predators, while it is nevertheless possible to obtain one or more measurements in such cases. All the regressions had very high correlation coefficents (Table 3) indicating that good predictions of body weight could be made from the linear measurements.

There is usually a good relationship between weight and volume in animals where the volume is expressed as length × girth^2 (McCulloch and Talbot 1965, Freeman and King 1969, Howells and Hanks 1975, Rideout and Worthen 1975). This relationship was also examined for the giraffe data and superior correlation coefficents were found (Table 3, Fig. 2). A more accurate prediction of liveweight could therefore be derived from this relationship.

Examination of logarithmic and semi-logarithmic transformations also yielded good correlations, the least good of these leaving less than 5 percent of the variation in weight unaccounted for, but in most cases *r* is better than 0.99. The most efficent equations are of the form

$$\log W = a(\log L + \log G) - b \quad (1)$$

$$\log W = a(\log LG^2) + b \quad (2)$$

The relationships between body weight and linear measurements of the giraffe are better than most of those reported by Talbot and McCulloch (1965) and McCulloch and Talbot (1965) for several species of African mammals and usually close to those reported by Krumrey and Buss (1968) in the female African elephant, Freeman and King (1969) for the black rhinoceros (*Diceros bicornis*) and Hanks (1972) also for the African elephant.

To what extent the relationships have been influenced by fluctuating weight due to seasonal effects, pregnancy, different stomach fill (Table 1), has not been investigated. Although McCulloch and Talbot (1965) have shown that in general the natural variations between individuals are as im-

portant as differences in fill, they also showed that the body measurements provided accurate estimates of weight that are independent of variation in fill, or body condition.

Freeman and King (1969) found no sex differences for the relationships in black rhinoceros, a species in which sexual dimorphism is not marked. McCulloch and Talbot (1965) found that for the species they worked on subdivision of the data into sex classes did not result in any marked increase in accuracy of the prediction derived. In the case of the giraffe, pooling the data not only effectively increased the range of weight variation, but also doubled the sample size and gave higher correlation coefficients. However, because significant differences in the regressions for the sexes were found, it seems possible that the higher correlation coefficients of the pooled data may be a function of sample size and that with larger samples better precision might be attained by separating males and females. Nevertheless, having a single prediction equation of good precision applicable to all giraffes, regardless of age, sex or time of collection, greatly enhances the practical value of such a formula.

As these data were all derived from the same population of giraffe it is likely that the results will be most accurate when used locally. However, in the absence of other data the methods can probably be used with confidence for any other population of giraffe in southern Africa including Zambia. (No statistically significant differences have been found in cranial measurements of giraffe from South Africa, South West Africa, Botswana, Rhodesia, Zambia, and Angola. Hall-Martin unpublished.)

CONCLUSIONS

From the equations presented it can be seen that reasonably accurate estimates of body and carcass weight of giraffe can be derived from dissected leg weights. Body weights can also be derived from linear measurements, but as measurements of height and length of giraffes are difficult to obtain and as such measurements are in any case usually subject to personal bias the measurement of girth probably offers the best method for obtaining an estimate of weight of a restrained live animal. Girth has also been shown (McCulloch and Talbot 1965, Rideout and Worthen 1975) to be the variable which consistently accounted for most of the variance of total body weight, in the species they examined. The relationships of the other 2 measurements are, however, also given, as accurate shoulder height measurements are often obtained from predator kills when no other measurements are possible.

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