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Using Linear Body Measurements to Predict Body Weight and Carcass Characteristics of Three Egyptian Fat-Tailed Sheep Breeds

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ABSTRACT

Five body measurements of 45 ram-lambs from Barki, Ossimi and Rahmani fat-tailed breeds (15 of each) were recorded at slaughter at 12 months of age to predict weights of live body and hot carcass. The measurements were body length, height at withers, heart girth, paunch girth and leg circumference. Simple correlation coefficients between body measurements with body weight and carcass traits were calculated. The stepwise procedure was used to select the variable for prediction equations of carcass composition. In Ossimi and Rahmani ram-lambs, body weight was significantly correlated with most measurements, while in Barki ram-lambs only heart girth was significantly correlated with body weight. All body measurements used to predict the weights of body and hot carcass had positive and significant regression coefficients. To predict total trimmed meat weight of Ossimi and Rahmani, heart girth must be included in the models with an accuracy of 0.66 and 0.89. The obtained results clearly indicate that weights of live body, hot carcass, total trimmed meat and total bone in carcasses could be predicted by measuring some live body measurements such as body length, heart girth, height at withers, leg circumference and paunch girth in ram-lambs of the three Egyptian breeds. Moreover, body length, withers height and leg circumference represented good body measurements to predict leg weight of the three Egyptian breeds (R^2 = 0.70).

Key words: Barki, Ossimi, Rahmani, prediction equations, body length, height at withers, heart girth, meat, bone weight

INTRODUCTION

The ultimate goal of the livestock and meat industry is to have an accurate and objective measurement method for assessing the economically important traits of animals and to determine the value and merit of the carcass while the animal is still alive (Boggs and Merkel, 1993). Linear measurements of body are kind of growth indicators in animal life (Goe *et al*., 2001; Attah *et al*., 2004), also it is likely determining these linear measurements would help to predict body weight and carcass traits in future (Atta and El-Khidir, 2004; Thiruvenkadan, 2005). Furthermore, body measurements used for several purposes including prediction of growth rate, genetic improvement, body condition, conformation and carcass traits (Lambe *et al*., 2008; Abdel-Mageed and Ghanem, 2013). In this context, measurements of various body conformation are of value in judging quantitative characteristics of meat and are also helpful in developing suitable selection criteria. Moreover, because of the relative ease in measuring linear dimensions they can be used as an indirect way to estimate live weight and carcass traits (Getachew, 2008; Getachew *et al*., 2009). According to Essien and Adesope (2003), linear body measurements are divided into skeletal and tissue measurements. Skeletal measurements include all height and length measurements while tissue measurements include heart girth, chest depth, punch girth and width of hips (Blackmore *et al*., 1958).

Body weight is a very important characteristic in animal husbandry due to selection criteria and economical profit (Cam *et al*., 2010a), particularly that animals have a balanced relationship between body weights and body measurements (Cam *et al*., 2010b). Although, body weight is an important economic trait in meat type animals, it is seldom measured in rural communal areas due to lack of scales. Sarti *et al*. (2003), Singh and Mishra (2004) and Edea *et al*. (2009) indicated that the best method of weighing animals without a scale is to predict body weight from body measurements and also some of body measurements could be used to predict carcass and meat quality (Lambe *et al*., 2008). Live weights and body measurements taken on live animals have been used expansively for a diversity of reasons both in experiments and in breeding and selection procedures (Cam *et al*., 2010a). The accuracy of functions used to predict live weight or growth characteristics from live animal measurements is of immense financial contribution to livestock production enterprise (Afolayan *et al*., 2006). When the producers and buyers of livestock are able to relate live animal measurements to growth characteristics, an optimum production and value-based trading systems will be realized from accurate predictions. This will ensure that livestock farmers are adequately rewarded rather than the middlemen and/or livestock product processors that tend to gain more profit in livestock production business, especially in the rural areas of developing countries (Afolayan *et al*., 2006; Safu *et al*., 2009). Under subtropical conditions, some trials were conducted to assess the relationship between body weight with body and carcass measurements in small ruminants (Abdel-Moneim, 2009a, b; Abdel-Mageed and Ghanem, 2013; Abd-Alla, 2014; Agamy *et al*., 2015). However, the purpose of the present study was to investigate the relationships among body measurements, body weight and carcass traits of lambs. Another aim was to establish prediction equations for body and hot carcass weights using live body measurements of Barki, Ossimi and Rahmani lambs.

MATERIALS AND METHODS

Experimental procedure: Animals used were forty five Barki, Ossimi and Rahmani fat-tail lambs (15 of each), aged 12 months, raised at the Small Ruminants Farm of Cairo University during the period from October, 2010 to September, 2011. Lambs were reared with their dams for four months post-lambing (suckling period). Then, they were kept free in semi-shaded open yards (5×8 m) with a 1.6 m high fence. Lambs were fed in groups according to their live body weight (NRC, 1985) on concentrate feed mixture (consisted of 55% yellow corn, 20% wheat bran, 10% cottonseed cake, 10% soybean cake, 2% limestone, 1.5% common slate, 1% minerals mixture and 0.5% sodium bicarbonate). In addition, lambs were fed on Egyptian clover (*Trifolium alexandrinum*), Darawa (*Zea mays* L.) or Egyptian clover hay according to their availability. Drinking water and mineral blocks were made available all the daytime. Ram-lambs were fasted for 18 h before slaughtering. They were weighted to the nearest 100 g and their linear body measurements were taken using a flexible measuring tape to the nearest 0.5 cm just before slaughtering. The linear body measurements estimated were:

- **Body length:** Distance from the anterior shoulder point to the posterior extremity of the pinbone
- **Height at withers:** Vertical distance from the highest point of the shoulder (withers) to the ground surface at the level of the fore legs
- **Heart girth:** The body circumference at a point immediately posterior to the front leg and shoulder and perpendicular to the body axis
- **Paunch girth:** Circumference of the body was measured immediately after the abdomen just before the hind legs
- **Leg or thigh circumference:** Girth from the posterior extremity of the pinbone to the top of the pinbone, leg circumference just under the body floor

All measurements were taken according to the suggestions of Birteeb *et al.* (2012), Musa *et al.* (2012a, b), Ravimurugan *et al.* (2012), Alvarez *et al.* (2013) and Younas *et al.* (2013).

Each carcass was deskinned and decapitated. Carcasses were weighed hot (about 1 h after slaughtering). Fat-tail was removed from ram-lambs carcasses and weighed. Each dressed carcass of 7 Barki, 8 Ossimi and 7 Rahmani was then longitudinally split into approximately two equal sides. The left side of carcass was then cooled at 4°C for 24 h. The chilled half of each carcass was weighed and divided into six cuts according to Atti and Hamouda (2004) and Abdel-Moneim (2009a, b). Each cut was then completely dissected into bone, fat (subcutaneous and intermuscular) and trimmed meat (including the nerves and connective tissue) were weighed separately. Dressing percentage, based on pre-slaughter body weight, was calculated. Body weight at slaughtering (12 months of age) averaged 34.1±0.25, 34.8±0.29 and 34.4±0.24 g for Barki, Ossimi and Rahmani ram-lambs, respectively.

Statistical analyses: Statistical analyses were conducted using SAS package program (SAS., 2004). Simple correlation coefficients between body measurements with each of body weight and carcass traits, within each breed, were calculated and tested for significance. To predict carcass composition traits of each breed based on body measurements, the stepwise procedure was used to select the variable for prediction equations. This procedure did not include variables with a $p>0.05$ as suggested by Diaz *et al.* (2004) and Marshall *et al.* (2005). The coefficient of determination (R^2) assessed the accuracy of the equations. Probability values <0.05 were taken as a significant level.

RESULTS AND DISCUSSION

Body measurements, body weight and carcass characteristics relationships: Body weight was significantly correlated with only heart girth in Barki and with all body measurements, except heart girth in Ossimi and leg circumference in Rahmani ram-lambs (Table 1). Heart girth, as well as chest depth were reported to have the highest correlation with body weight in lambs and kids by other authors (Nigm *et al.*, 1995; Shaker and Hammam, 2008; Abdel-Moneim, 2009b; Abdel-Mageed and Ghanem, 2013). Consequently, it may be suggested that prediction of body weight of Ossimi and Rahmani ram-lambs could be depend on many body measurements but in case of Barki, the only recommended body measurement to predict body weight is heart girth. In most studies, heart girth was found to be highly correlated with body weight in sheep (Atta and El-Khidir, 2004; Topai and Macit, 2004; Afolayan *et al.*, 2006) and in goat (Nsoso *et al.*,

Table 1: Correlation coefficients between body measurements, body weight and carcass traits of Barki, Ossimi and Rahmani ram-lambs

				Weight				
				Hot carcass				
Body measurements	Body weight	Tail weight	Dressing[1] (%)	With tail	Without tail	Trimmed meat	Dissected fat	Bone
Body length								
Barki	0.43 (15)	0.21 (15)	0.40 (15)	0.48 (15)	0.50 (15)	-0.14 (7)	-0.36 (7)	0.38 (7)
Ossimi	0.77** (15)	0.57* (15)	0.10 (15)	0.76** (15)	0.71** (15)	0.80* (8)	0.51 (8)	0.71* (8)
Rahmani	0.75** (15)	0.60* (15)	0.58* (15)	0.76** (15)	0.76** (15)	0.54 (7)	-0.24 (7)	0.59 (7)
Height at withers								
Barki	0.11 (15)	0.28 (15)	-0.15 (15)	-0.04 (15)	-0.08 (15)	0.06 (7)	-0.18 (7)	0.49 (7)
Ossimi	0.64* (15)	0.41 (15)	0.40 (15)	0.70** (15)	0.70** (15)	0.63 (8)	0.31 (8)	0.74* (8)
Rahmani	0.67** (15)	0.68** (15)	0.33 (15)	0.65** (15)	0.62* (15)	0.16 (7)	0.11 (7)	0.19 (7)
Heart girth								
Barki	0.52* (15)	0.37 (15)	0.51 (15)	0.64* (15)	0.65* (15)	0.60 (7)	0.06 (7)	0.42 (7)
Ossimi	0.20 (15)	-0.10 (15)	0.11 (15)	0.22 (15)	0.31 (15)	0.81* (8)	0.65 (8)	0.66 (8)
Rahmani	0.89** (15)	0.60* (15)	0.54* (15)	0.88** (15)	0.89** (15)	0.83* (7)	0.14 (7)	0.62 (7)
Paunch girth								
Barki	0.49 (15)	0.42 (15)	0.16 (15)	0.33 (15)	0.31 (15)	0.55 (7)	0.67 (7)	0.38 (7)
Ossimi	0.71** (15)	0.21 (15)	-0.14 (15)	0.63* (15)	0.69** (15)	0.49 (8)	0.00 (8)	0.20 (8)
Rahmani	0.88** (15)	0.71** (15)	0.35 (15)	0.84** (15)	0.83** (15)	0.36 (7)	0.54 (7)	0.50 (7)
Leg circumference								
Barki	0.01 (15)	-0.20 (15)	-0.04 (15)	-0.04 (15)	-0.01 (15)	-0.19 (7)	-0.40 (7)	0.19 (7)
Ossimi	0.73** (15)	0.52* (15)	-0.06 (15)	0.67** (15)	0.64** (15)	0.77* (8)	0.60 (8)	0.59 (8)
Rahmani	0.34 (15)	-0.01 (15)	0.18 (15)	0.32 (15)	0.36 (15)	0.32 (7)	0.13 (7)	-0.18 (7)

(..) Value between brackets beside each coefficient shows the number of observations, *p<0.05, **p<0.01, [1] Fat-tail weight included

2003; Khan *et al*., 2006; Abdel-Mageed and Ghanem, 2013; Abd-Alla, 2014). In this context. This result partly agrees with that obtained by Shehata (2013) who stated that live body weight and body measurements (body length, heart girth and height at withers) have positive and high correlations ($p<0.01$).

The heavy fat-tail is not preferred by middle class that represents the majority of Egyptian mutton consumers. While it is preferred by those belonging to lower class consumers Those are accustomed to use tail fat in cooking. Both consumers, however, are concerned about the approximate estimation of lamb tail weight. In Ossimi ram-lambs, significant correlations were recorded for tail weight with body length and leg circumference (Table 1).

Tail weight of Rahmani lambs was significantly correlated with all body measurements recorded except leg circumference. This finding partly agrees with that of Abdel-Moneim (2009b) who reported that tail weight of Rahmani carcass was positively and significantly correlated with each of height at withers ($p<0.01$), heart girth ($p<0.05$), round circumference ($p<0.05$), paunch girth ($p<0.05$) and pelvic width ($p<0.05$). In this context. Yaprak *et al*. (2008) found that height at withers of Red Karaman lambs was positively and significantly ($p<0.05$) correlated with tail weight. Consequently, live lamb purchaser can predict tail weight from the aforementioned body measurements in only two breeds, Ossimi and Rahmani. But, he can not use any body measurement for predicting Barki fat-tail weight, that is in accordance with the findings of Agamy *et al*. (2013). Similar result was recorded by Abdel-Moneim (2009b) who concluded that no significant correlation were obtained between tail weight and body measurements of Barki ram-lambs. But dissimilar result was reported by Shehata (2013) who indicated that the fat-tail weight of Barki lambs carcass was correlated with body length (60%), heart girth (60%) and height at withers (47%), respectively.

Table 2: Prediction equations for calculating body weight (kg) from body measurements (cm) of Egyptian ram-lambs

Breed	Steps	Variables	p	R^2	SE
Barki	1	HG	*	0.27	0.28
Body weight = -12.44+0.62 HG (cm)					
Ossimi	1	BL	**	0.60	0.32
Body weight = -53.65+1.41 BL (cm)					
Rahmani	1	HG	**	0.80	0.16
	2	BL	**	0.92	0.12
Body weight = -91.58+0.90 HG (cm)+0.71 BL (cm)					
All breeds	1	BL	**	0.58	0.16
	2	HW	**	0.70	0.18
	3	PG	**	0.75	0.12
Body weight = -89.97+0.88 BL (cm)+0.58 HW+0.35 PG (cm)					

HG: Heart girth, BL: Body length, HW: Height at withers, PG: Paunch girth, R^2: Coefficient of determination, p: *$p<0.05$, **$p<0.01$, SE: Standard error

Dressing percentage represents an important parameter for both meat trader and consumer (Akcapinar, 2000). Unfortunately our results revealed no significant correlation between body dimensions and dressing percentage in Barki and Ossimi ram-lambs. Some correlations, however, were negative. This result agrees with that obtained by Yaprak *et al*. (2008) who reported that height at withers, body length and heart girth circumference of Red Karaman lambs were not significantly correlated with dressing percentage. In case of Rahmani ram-lambs, significant correlations were obtained for body length and heart girth with dressing percentage. This finding partly agrees with that of Attah *et al*. (2004) who noticed that chest girth of Red Sokoto and West African Dwarf yearling goats slaughtered at 10 and 20 kg body weights was highly correlated ($p<0.01$) with dressing percentage. Accordingly, both measurements (body length or heart girth) could be adopted in selecting higher dressing percentage of this breed. It may be pointed out that the attained trimmed meat, dissected fat and bone weights are similar to those previously reported (Shaker and Hammam, 2008) on the same breeds.

It is interesting that correlations among body measurements and carcass weight, whether with or without tail, behaved nearly similarly as correlations between body weight and measurements. In other words, differences in fat-tail weight, whether within or among breeds did not result in concomitant differences in carcass weights of the three studied breeds.

The modern local mutton consumer is looking for more percentage of meat. Trimmed meat weight in Ossimi ram-lambs was significantly ($p<0.05$) and positively correlated with three body dimensions, i.e., body length, heart girth and leg circumference. In Rahmani ram-lambs, trimmed meat weight was significantly ($p<0.05$) and positively correlated with only heart girth. Consequently, it may be suggested to take these measurements into consideration when more meat is targeted by lamb consumer. It may be indicated that fat deposits are subjected to certain nutritional and physiological aspects. Hence, it seems difficult to access its weight especially in lambs. Bone weight showed significant correlations with body length and height at withers of Ossimi ram-lambs.

Prediction equations for body and carcass weights using body measurements: Heart girth per se contributed 27 % of the variation in body weight of Barki lambs (Table 2). While body length represented 60% of the variation in body weight of Ossimi ram-lambs. In the meantime, the best equation for predicting live body weight of Rahmani lambs was attained when heart girth and body length were included in the equation with coefficient of determination (R^2) being 92%.

Table 3: Prediction equations for calculating tailed hot carcass weight (kg) from body measurements (cm) of Egyptian ram-lambs

Breed	Steps	Variables	p	R^2	SE
Barki	1	HG	*	0.41	0.17
Tailed hot carcass weight = -20.99+0.50 HG (cm)					
Ossimi	1	BL	**	0.58	0.15
Tailed hot carcass weight = -21.17+0.54 BL (cm)					
Rahmani	1	HG	**	0.77	0.10
	2	BL	*	0.85	0.14
Tailed hot carcass weight = -43.39+0.48 HG (cm)+0.36 BL (cm)					
All breeds	1	BL	**	0.58	0.11
	2	HW	*	0.70	0.10
Tailed hot carcass weight = -48.88+0.61 BL (cm)+0.42 HW (cm)					

HG: Heart girth, BL: Body length, HW: Height at withers, R^2: Coefficient of determination, p: *p<0.05, **p<0.01, SE: Standard error

Table 4: Prediction equations for calculating un-tailed hot carcass weight (kg) from body measurements (cm) of Egyptian ram-lambs

Breed	Steps	Variables	p	R^2	SE
Barki	1	HG	*	0.42	0.15
Un-tailed hot carcass weight = -18.46+0.45 HG (cm)					
Ossimi	1	BL	**	0.50	0.13
Un-tailed hot carcass weight = -19.03+0.38 BL					
Rahmani	1	HG	**	0.78	0.09
	2	BL	*	0.85	0.13
Un-tailed hot carcass weight = -38.83+0.44 HG (cm)+0.31 BL (cm)					
All breeds	1	BL	**	0.55	0.10
	2	HW	**	0.65	0.09
	3	HG	*	0.69	0.06
Un-tailed hot carcass weight = -39.90+0.43 BL (cm)+0.25 HW (cm)+0.16 HG (cm)					

HG: Heart girth, BL: Body length, HW: Height at withers, R^2: Coefficient of determination, p: *p<0.05, **p<0.01, SE: Standard error

These findings are in harmony with that of Nigm *et al*. (1995) who found that heart girth was the best single predictor and accounted alone for 77% of the variation in body weight of Merino males. Abdel-Moneim (2009b) found that body length and heart girth accounted for 47 and 86% in body weight of Barki and Rahmani, respectively, whereas both paunch girth and body length represented 93% of the variation in Ossimi body weight.

Regardless of breed, the equation including body length, withers height and paunch girth could predict body weight of Egyptian ram-lambs with an accuracy of 75% (Table 2). This finding is confirmed by Abdel-Moneim (2009b) who found that body length and paunch girth could predict body weight of Egyptian lambs with an accuracy of 64%. However, the accuracy was higher (0.88) when the equation of prediction including heart girth and body length in subtropical goat kids (Abdel-Mageed and Ghanem, 2013). It could be noticed that all body measurements used to predict body weight of lambs had positive regression coefficients indicating that body weight of lambs increased as those measurements increased.

Results in Table 3 and 4 showed that the same variables could be used to predict both tailed and un-tailed hot carcass weight with nearly equal determination coefficient. In prediction of tailed hot carcass weight of Barki ram-lambs, only heart girth was included in the model with 0.41 for R^2 value. In Ossimi, body length was the only variable included in the model to predict tailed hot carcass weight with accuracy 0.58. While both heart girth and body length contributed to the variation in hot carcass weight of Rahmani ram-lambs with high R^2 (0.85). Similar result was arrived at by Nigm *et al*. (1995), for Merino lambs, as heart girth was the most significant variable for prediction of hot carcass weight. Where R^2 was 0.73, entry of chest depth increased R^2 to 0.80.

As a general recommendation, it may be suggested to use two body measurements (body length and withers height) to predict hot carcass weight of Egyptian lambs (Table 3). Body length was the most significant (p<0.01) variable for estimating hot carcass weight (R^2 = 0.58). Coefficient of

Table 5: Prediction equations for calculating total trimmed meat weight (kg) from body measurements (cm) of Egyptian ram-lambs

Breed	Steps	Variables	p	R^2	SE
Ossimi	1	HG	*	0.66	0.11
Total trimmed meat = -18.03+0.38 HG (cm)					
Rahmani	1	HG	**	0.89	0.15
Total trimmed meat = -29.86+0.51 HG (cm)					
All breeds	1	HG	**	0.57	0.07
	2	BL	**	0.72	0.07
Total trimmed meat = -31.61+0.36 HG (cm)+0.21 BL (cm)					

HG: Heart girth, BL: Body length, R^2: Coefficient of determination, p: *p<0.05, **p<0.01, SE: Standard error

Table 6: Prediction equations for calculating total bone weight (kg) from body measurements (cm) of Egyptian ram-lambs.

Breed	Steps	Variables	p	R^2	SE
Ossimi	1	HW	*	0.54	0.03
Total bone weight = -2.32+0.09 HW (cm)					
All breeds	1	BL	**	0.44	0.02
	2	HG	*	0.61	0.02
	3	HW	*	0.69	0.02
Total bone weight = -6.11+0.05 BL (cm)+0.05 HG (cm)+0.04 HW (cm)					

HW: Height at withers, BL: Body length, HG: Heart girth, R^2: Coefficient of determination, p: *p<0.05, **p<0.01, SE: Standard error

determination was improved to 0.70 by incorporating withers height into the prediction equation. However, lower R^2 estimate (0.53) was reported by Abdel-Moneim (2009b) to predict hot carcass weight of Egyptian lambs by using body length and withers height. The obtained results in the present study are in harmony with those already reported by Seker and Kul (2001), Marshall *et al*. (2005), Alsheikh *et al*. (2007) and Shaker and Hammam (2008). Seker and Kul (2001) showed that height at withers, height at rump, body length, chest width and rump width of Awassi yearling lambs may be used for predicting the warm carcass weight. Alsheikh *et al*. (2007) found that the regression coefficient of carcass weight on principle components of body size of fattened Barki lambs were positive and significant (p<0.05). Furthermore, Shaker and Hammam (2008) reported that the best equation for predicting carcass weight of Barki lambs was attained when live body weight, body height and thick tail circumference were incorporated (R^2 = 0.90).

Modern mutton consumer in Egypt is looking for less fat and high content of lean in sheep's meat. To predict total trimmed meat weight (Table 5) results showed that heart girth can be included in equations for Ossimi and Rahmani (R^2 = 0.66 and 0.89, respectively) while no variables reached significant level for Barki ram-lambs. Accordingly, it may be recommended to consider heart girth as an indicator of protein content in Ossimi and Rahmani carcasses. On the other hand, irrespective of breed, heart girth contributed for 57% of the total variation in trimmed meat weight of Egyptian ram-lambs. Whereas, body length came next and scored a partial determination of 0.15 increasing the model's R^2 to 0.72.

Results in Table 6 showed that three variables were included to predict total bone weight of the three studied Egyptian breeds. The first of these was body length, it explained 44% of the variation in total bone weight. The remaining variables were heart girth and withers height. When these two body measurements were included in the model, the accuracy increased by 25%. Similarly, only withers height could be included to predict total bone weight of Ossimi carcass (R^2 = 0.54). Whereas, no variables reached the significance level to predict total bone weight in carcasses of Barki and Rahmani.

In this context, it was found that body length, withers height and leg circumference represented good body measurements to predict leg weight of the three Egyptian breeds (R^2 = 0.70). Unfortunately, our results revealed that no body measurements could be used to predict total dissected carcass fat in Egyptian ram-lambs. No variables reached the significance level to predict total dissected carcass fat weight in Barki, Ossimi and Rahmani. Further studies should be carried out to find out suitable measurements for predicting fat content in carcasses of Egyptian ram-lambs.

CONCLUSION

Weights of live body and hot carcass, total trimmed meat and total bone in carcasses of Egyptian ram-lambs could be predicted by measuring some live body measurements such as body length, heart girth, height at withers, leg circumference and paunch girth. In the meantime, this study revealed that no body measurements could be used to predict total dissected carcass fat weight. Additionally, it was noticed that all body measurements used to predict the weights of body and hot carcass had positive and significant regression coefficients.

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