Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.8, No.8, 2018

Assessment of Relationship Between Body Weight and Biometric Traits Using Path Analysis in Kenyan Domesticated Rabbits

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This research is financed by the Research, Production and Extension (RPE) Division - JKUAT

Abstract
Rabbit raring in Kenya is a steadily growing industry which is contributing towards enhancing household food security and income of resource poor farmers. Relationship between body weight and eight biometric traits (ear length, tail length, nose-to-shoulder length, chest circumference, thigh circumference, abdominal circumference, body length and rump width) was determined in 430 rabbits comprising 255 females and 175 males using path analysis. The animals were randomly sampled from thirteen counties in Kenya. Pair-wise correlations among body weights and linear body measurements were positive and highly significant (r = 0.250-0.703; P<0.01 for male rabbits and r = 0.193-0.671; P<0.01 for female rabbits). Path analysis revealed that the highest direct effect on body weight in male rabbits was realized through chest circumference followed by body length, ear length, thigh circumference and tail length in that order. The direct effects of abdominal circumference and rump width were statistically not significant (P>0.05) while nose-to-shoulder length had negative direct effect, hence these variables were excluded from the final regression model. The final regression equation of the male rabbits included ear length, tail length, chest circumference, thigh circumference and body length with a coefficient of determination (R^2) of 0.636. Path analysis for the female rabbits showed highest direct effects was realized via chest circumference followed by body length then ear length in that order. The direct effect of tail length, abdominal circumference and rump width were not significant (P>0.05) while nose-to-shoulder length had a negative direct effect on body weight, hence all these variables were excluded from the final regression model. The final regression equation for the female rabbits included ear length, chest circumference and body length with a coefficient of determination (R^2) of 0.567. The prediction coefficients obtained in this study could therefore be used in weight estimation and breeding programs to improve meat production in rabbits.
Keywords: Body weight, biometric traits, path analysis, rabbits, Kenya.

Introduction

Rabbit farming in the developing countries has been identified as an option to alleviate poverty among the resource poor farmers (Oseni & Lukefahr, 2014). Rabbits, which are an unconventional source of protein for Kenyans, are fast gaining popularity in enhancing household food security and as a source of income (Mwangi et al., 2014). Beneficial attributes of rabbits that are being exploited include: easy to keep and manage, fast growth, short gestation period, early sexual maturity, ability to rebreed shortly after kindling and short generation interval (Udeh, 2013). The rabbit meat has low cholesterol and therefore heart patient friendly, high percentage protein which is easily digestible, low sodium content in comparison to other meats, high calcium and phosphorus contents, high ratio of meat to bone hence more edible meat on the carcass, highly nutritious and can be used in a variety of recipes (Hassan et al., 2012). These qualities confer on rabbits a potential to bridge the shortage of healthy animal protein in developing countries thus contributing significantly towards addressing malnutrition crisis (Moreki & Seabo, 2012).

In animal breeding, genetic improvement of livestock is mainly done by selecting animals with higher body weights and biometric traits (Önder & Hasan, 2015). The use of body measurements is important in defining performance in livestock and relationships between body measurements and performance traits have been reported (Cam et al., 2010). The decision to use an indirect measurement (biometric traits) for growth selection purpose is dependent on the ease to take measurements and how the biometric traits predict body weight (Hassan et al., 2012). Body weight and biometric traits objectively measured would facilitate selection for growth by enabling the breeders identify early maturing and late maturing animals of different sizes (Yakubu & Mohammed, 2012). Animal growth results from increase in body weight (mass) and changes in the body conformation (shape) of the various body parts which can help estimate meat production (Okpeku et al., 2011). Therefore breeders can use biometric traits as a criterion in selection programs since these body measurements and related selection indices not only enable breeders predict body weight but they also act as important functional indicators in animal production (Jafari & Hashemi, 2014). Knowing the body weight could also aid the farmers on proper feeding, monitoring growth and efficient health care of the animals (Shirzeyli et al., 2013).

The biometric traits have already been suggested as the measurable trait that can be used to characterize rabbits, contrast their variation in size and shape and to predict carcass and body weight (Udeh, 2013). However, body weight is not easily measured in the field due to the time and energy expended while determining it and the resource poor local farmers may not be able to afford the weighing scales. Therefore the best way out to weigh animals would be to regress body weight as a certain number of body characteristics which can easily be measured (Yakubu & Mohammed, 2012).

Path analysis has been used widely in the animal breeding practices and describes the directed dependencies among a set of variables, and the body weight is often selected as a response variable from explanatory variable. This is aimed at explaining the body weight from the explanatory variables while also putting the indirect effects into consideration (Önder & Hasan, 2015). The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components. One component is the path coefficient (or standardized partial regression coefficient) that measures the direct effect of the predictor variable upon its response variable. The other component is the indirect effects of a predictor variable on the response variable through the predictor variables (Marjanović-Jeromela, et al., 2008).

The relationship between body weight and biometric traits of domesticated Kenyan rabbits has not been examined using classical statistical tool such path analysis. The objective of this study was to establish direct and indirect relationship between body weight and biometric body measurements of domesticated Kenyan rabbits and also to develop functional prediction model for body weight using different body measurements.

Materials and Methods

Location of the Study and Animals

A total of 13 counties in Kenya were considered for this study conducted between February and August, 2016. The counties in Western Kenya that were included in the study were Bungoma, Busia, Vihiga and Kakamega counties. In Eastern Kenya, the selected counties were Kitui, Machakos and Makueni Counties. In the Rift Valley region they were Bomet, Uasin Gishu and Nandi Counties while in the Central Kenya they were Kirinyaga, Nyandarua and Laikipia counties.

Rabbits were randomly selected from farmers in each selected county. A total of four hundred and thirty rabbits comprising 255 females and 175 males were randomly sampled from farmers in towns and villages.

Traits Measured

Body Weight (BW) along with eight biometric traits were measured. The biometric traits were: Ear length (EL), Tail Length (TL), Nose-to-Shoulder Length (NSL), Chest Circumference (CC), Thigh Circumference (TC), Abdominal Circumference (AC), Body Length (BL) and Rump Width (RW). Body Weight (BW) was taken using a 10-KG weigh scale while the biometric traits were taken using a flexible measuring tape.

Data Analysis

Means, standard deviations (SD) and coefficients of variation (CV) of the body weight and linear body measurements of the rabbits were computed. Pairwise correlations among body weight and morphometric characters were also determined separately for each sex. Standardized partial regression coefficients called path coefficients (beta weights) were calculated, too. This was to allow direct comparison of values to reflect the relative importance of independent variables in order to explain variation in the dependent variable (Marjanović-Jeromela et al., 2008).

The path coefficient from an explanatory variable (X) to a response variable (Y) as described by Mendes et al., (2005) is shown below:

Where:

$P_{Y.Xi}$ = path coefficient from Xi to Y (i = EL, TL, NSL, CC, TC, AC, BL, RW),

$$\mathbf{P_{Y.Xi} = b_i \frac{S_{Xi}}{S_Y}}$$

b_i = partial regression coefficient,

S_{xi} = standard deviation of X_i,

S_Y = standard deviation of Y.

The multiple linear regression model adopted was:

$$\mathbf{Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + e}$$

Where:

Y = endogenous variable (body weight),

a = intercept,

b's = regression coefficients,

X's = exogenous variables (EL, TL, NSL, CC, TC, AC, BL, RW) e = error term, normally distributed with mean zero and variance.

RESULTS AND DISCUSSION

Descriptive statistics of the body weight and the linear body measurements are shown in Table 1. The body weight (kg), ear length, tail length, nose-to-shoulder length, chest circumference, thigh circumference, abdominal circumference, body length and rump width averaged 2.72, 11.30, 8.40, 13.35, 25.45, 16.92, 28.42, 45.73, and 4.43 respectively. The body length and abdominal circumference were longer and the body weight heavier than the rabbit breeds reported by Olawumi (2014) in the humid tropics of Nigeria. The high variability in the body weight might not be unconnected with great environmental influence such as temperature and nutrition on this variable. This variation therefore, could serve as a basis for the genetic improvement of body weight.

Table 1: Descriptive statistics of body weight and body dimensions of Rabbits

	N	Mean	Std. Deviation	CV
EAR LENGTH(CM)	430	11.30	1.0678	9.452067
TAIL LENGTH(CM)	430	8.40	1.5202	18.09977
NOSE TO SHOULDER LENGTH(CM)	430	13.35	2.659	19.9176
CHEST CIRCUMFERENCE(CM)	430	25.45	3.2398	12.72956
THIGH CIRCUMFERENCE(CM)	430	16.92	3.1587	18.67175
ABDOMINAL CIRCUMFERENCE(CM)	430	28.42	4.6565	16.38689
BODY LENGTH(CM)	430	45.73	4.4598	9.75246
RUMP WIDTH(CM)	430	4.43	1.0208	23.0273
BODY WEIGHT(KGS)	430	2.72	0.6857	25.19104

Bivariate Correlations

Pairwise correlations among body weight and linear body measurements of the two sexes are presented in Table 2. The association between body weight and the ear length, chest circumference, thigh circumference, abdominal circumference and body length was observed to be strong in both sexes. There was a significant association between body weight and the biometric traits in both sexes ($P<0.01$). The correlations between body weight and each biometric trait were higher for the males (0.250 - 0.703) compared to the females (0.193 - 0.671). For the males, the correlations were higher and significant between body weight and ear length, chest circumference, thigh circumference, abdominal circumference and body length (0.644, 0.690, 0.567, 0.527 and 0.703 respectively; $P<0.01$) and lower but significant for tail length, nose-to-shoulder length and rump width (0.413, 0.250 and 0.343 respectively, $P<0.01$). The correlations in the females was higher and significant between body weight and ear length, chest circumference, thigh circumference, abdominal circumference and body length (0.569, 0.663, 0.556, 0.507 and 0.671 respectively; $P<0.01$) and lower but significant for tail length, nose-shoulder-length and rump width (0.193, 0.197 and 0.372 respectively; $P<0.01$).

The results obtained in this study showed that the increase in the body weight was positively correlated to the biometric traits that were taken. These results were similar to the findings by Olawumi (2014) who also established positive correlation between body weight and linear body measurements of rabbits in the humid tropic Nigeria. In a study by Zhan-fu *et al* (2008) on Saibei rabbits, they also established positive correlation between body weight and phenotypic measurements. The inference from the positive relationships in the present study is that body weight could be estimated from body measurements, especially under village conditions where scales are not readily available. The association may also be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (pleiotropy).

Table 2: Phenotypic correlations among body weight and body measurements of Rabbits according to sex*

	BW(KGS)	EL(CM)	TL(CM)	NSL(CM)	CC(CM)	TC(CM)	AC(CM)	BL(CM)	RW(CM)
BW(KGS)	1	.644**	.413**	.250**	.690**	.567**	.527**	.703**	.343**
EL(CM)	.569**	1	.325**	.287**	.563**	.492**	.483**	.629**	.228**
TL(CM)	.193**	.247**	1	-.064	.229**	.180*	.125	.378**	0.006
NSL(CM)	.197**	.237**	.026	1	.619**	.467**	.597**	.485**	.358**
CC(CM)	.663**	.504**	.162**	.520**	1	.677**	.842**	.722**	.456**
TC(CM)	.556**	.413**	.129*	.438**	.704**	1	.579**	.551**	.241**
AC(CM)	.507**	.420**	.094	.539**	.802**	.602**	1	.583**	.389**
BL(CM)	.671**	.576**	.274**	.438**	.647**	.605**	.469**	1	.421**
RW(CM)	.372**	.322**	.150*	.310**	.580**	.333**	.507**	.340**	1
	**. Correlation is significant at the 0.01 level (2-tailed).								
	*. Correlation is significant at the 0.05 level (2-tailed).								
	Upper matrix: Male rabbits								
	Lower matrix: Female rabbits								

Analysis of Variance of the Regression

The analysis of variance for the regression model of the rabbits is shown in Table 3. The $F_{calculated}$ was significant (P<0.01), indicating reliance on the prediction of body weight from biometric measurements of the rabbits.

Table 3. Analysis of Variance (ANOVA) for regression

Model	Sum of Squares	Degree of Freedom	Mean Square	F
Regression	129.646	8	16.206	94.287**
Residual	71.845	418	.172	
Total	201.491	426		

**Significant at P< 0.01

Path coefficients of body dimensions

The path coefficients of the body dimensions for the female rabbits were as shown in Table 4. Path coefficient (PC) or direct effect of ear length on body weight was positive (PC=0.174) and statistically significant as revealed by the t-test. The correlation between ear length and body weight was mainly due to indirect effects of body length. Chest circumference had the highest positive influence on the body weight (PC= 0.368) while none of the indirect effects was as high as the direct effect. The body length also had a high and positive direct effect on the body weight (PC= 0.365) with the highest indirect effect mainly resulting through the chest circumference. The direct effect of the nose-to-shoulder length was negative and statistically significant from the t-test (PC= -0.265) with the highest indirect effect realized through the chest circumference. The direct effects of thigh circumference and abdominal circumference were both positive but statistically insignificant (PC= 0.080 and 0.061 respectively). The direct effect of the rump width on the body length was negative and statistically insignificant (PC= -0.001).

Table 4. Direct and indirect effect of linear type traits on body weight of female rabbits

Trait	Correlation coefficient with body weight	Direct effect	Indirect effect							
			EL	TL	NSL	CC	TC	AC	BL	RW	Total
EL	.569	0.174**		-0.006	-0.065	0.181	0.029	0.032	0.217	0.001	0.388
TL	.193	0.029^{ns}	0.053		-0.007	0.058	0.009	0.007	0.103	0.000	0.224
NSL	.197	-0.265**	0.051	-0.001		0.187	0.031	0.041	0.165	0.001	0.475
CC	.663	0.368**	0.096	-0.004	-0.144		0.050	0.061	0.243	0.002	0.305
TC	.556	0.080^{ns}	0.079	-0.003	-0.121	0.253		0.046	0.227	0.001	0.482
AC	.507	0.061^{ns}	0.080	-0.002	-0.149	0.288	0.043		0.176	0.002	0.438
BL	.671	0.365**	0.110	-0.007	-0.121	0.232	0.043	0.036		0.001	0.294
RW	.372	-0.001^{ns}	0.062	-0.004	-0.086	0.208	0.024	0.039	0.128		0.370

** Significant at P<0.05; ns (not significant)

Table 5 presents the path coefficients for the male rabbits. Ear length had a positive and statistically significant direct effect on the body weight (PC= 0.215) with the highest indirect effect realized through the chest circumference. For the males, just like in the females, highest direct influence on the body weight was realized from the chest circumference (PC= 0.458). The body length had a high direct effect on the body weight (PC= 0.267) realized mainly through the chest circumference. This direct effect was however lower than that established in the female rabbits. The direct effects from the tail length and thigh circumference on the body weight were positive (PC= 0.107 and 0.136 respectively) realized indirectly mainly through the chest circumference. The direct effect of the nose-to-shoulder length was negative but statistically significant (PC= -0.255). The direct effects of the abdominal circumference and rump width on the body weight were statistically insignificant as revealed by the t-test.

These findings were in harmony with those of Zhan-fu et al., (2008) who using path analysis, found out that body length and chest girth were the parameters with the highest direct influence on body weight in a study on the Saibei rabbits. It also conformed to a related study done by Yakubu, (2010) on the Yankasa lambs which established that body length and heart girth (chest circumference) had the highest direct effects on the body weight from the path analysis.

Table 5. Direct and indirect effect of linear type traits on body weight of male rabbits

Trait	Correlation coefficient with body weight	Direct effect	Indirect effect							
			EL	TL	NSL	CC	TC	AC	BL	RW	Total
EL	.644	0.215**		0.035	-0.073	0.258	0.067	-0.040	0.168	0.014	0.429
TL	.413	0.107**	0.070		0.016	0.105	0.024	-0.010	0.101	0.000	0.307
NSL	.250	-0.255**	0.062	-0.007		0.284	0.064	-0.049	0.129	0.022	0.505
CC	.690	0.458**	0.121	0.005	-0.158		0.092	-0.069	0.193	0.028	0.213
TC	.567	0.136**	0.106	0.019	-0.119	0.310		-0.047	0.147	0.015	0.431
AC	.527	-0.082^{ns}	0.104	0.013	-0.152	0.386	0.079		0.156	0.024	0.609
BL	.703	0.267**	0.135	0.040	-0.124	0.331	0.075	-0.048		0.026	0.436
RW	.343	0.062^{ns}	0.049	0.001	-0.091	0.209	0.033	-0.032	0.112		0.281

** Significant at P<0.05; ns (not significant)

Establishment of Preliminary Regression Equations

The preliminary regression equation for the male rabbits with a coefficient of determination (R^2) value of 0.678 obtained from the simple correlations among body weight and linear body measurements was:

$Y = -2.699 + 0.124EL + 0.051TL – 0.061NSL + 0.090CC + 0.027TC – 0.011AC + 0.039BL + 0.034RW$

The preliminary regression equation for the female rabbits with a coefficient of determination (R^2) value of 0.617 obtained from the simple correlations among body weight and linear body measurements was:

$Y = - 3.003 + 0.118EL + 0.013TL – 0.070NSL + 0.081CC + 0.018TC + 0.009AC + 0.057BL + 0.000RW$

Establishment of Final Regression Equation for Male Rabbits

In the male rabbits, despite the fact that the simple correlation between body weight and abdominal circumference was fairly high ($r = 0.527$), the direct effect of the abdominal circumference on the body weight was negative and statistically insignificant. It was therefore deleted from the final regression model. The nose to shoulder length had a significant direct effect on the body weight, however, it was deleted from the final regression model since the effect was negative. The rump width was also excluded from final regression model since its direct effect on body weight was statistically insignificant. Yakubu (2010), established that in estimating the body weight of animals from the linear body measurements, it is important to delete the less significant variables in the final regression model. Therefore the final regression model for the male rabbits only had the ear length, tail length, chest circumference, thigh circumference and body length whose contribution to the model were both positive and statistically significant. The final regression equation for the male rabbits was:

$Y = -2.858 + 0.135EL + 0.080TL + 0.056CC + 0.020TC + 0.034BL$

The coefficient of determination (R^2) in the final regression model of male rabbits was 0.636 which was slightly lower than that of the preliminary regression model ($R^2 = 0.678$). This means that there was a small impact on the accuracy of the regression model upon exclusion of nose to shoulder length, abdominal circumference and rump width which were redundant variables.

Establishment of Final Regression Equation for Female Rabbits

In the female rabbits, the simple correlation for thigh circumference and abdominal circumference with the body weight were fairly high ($r = 0.556$ and 0.507 respectively) but their direct effects on the body weight were statistically not significant, hence they were excluded from the final regression model. The direct effect of nose to shoulder length on body weight was statistically significant but this variable was excluded from the final regression model since the effect was negative. The tail length was also not included in the final regression model since its direct effect on the body weight was statistically not significant. Therefore the final regression model for female rabbits selected after eliminating the redundant variables only included the ear length, chest circumference and body length which were all positive and statistically significant in their direct influence on the body weight. The final regression equation for the female rabbits obtained was:

$Y = -3.108 + 0.139EL + 0.077CC + 0.051BL$

The coefficient of determination (R^2) obtained in the final female rabbits' regression model was 0.567 which was slightly below that of the preliminary regression model ($R^2 = 0.617$). Therefore, deletion of the tail length, nose to shoulder length, thigh circumference, abdominal circumference and rump width had a slightly small impact on the accuracy of the final regression model.

The present findings did underscore the importance of using the linear body measurements to predict body weight of animals as already established by related studies on goats (Yakubu & Mohammed, 2012) and sheep (Cam et al, 2010; Shirzeyli et al., 2013; Tyasi & Tyasi, 2015; Yakubu, 2010). In a related study on rabbits, Udeh, (2013) was able to also establish the body weight of rabbits using the linear body measurements. In another study on rabbits, Zhan-fu et al., (2008) through the use of path analysis was able to predict the body weight of Saibei rabbits from the linear body measures and found out that body length and chest girth had the highest direct effect on the body weight.

CONCLUSION

From the simple correlations, it was established that for both the male and the female rabbits, the body weight was positively and highly correlated to body length, chest circumference, ear length, thigh circumference and abdominal circumference. Body weight was also positively but lowly correlated to tail length, rump width and nose to shoulder length. However, path analysis revealed that for the female rabbits, the direct effects of tail length, abdominal circumference and rump width on the body weight were statistically insignificant while nose to shoulder had a negative direct effect on body weight. The positive direct effects on the body weight were mainly realized via the chest circumference, body length, and ear length in that descending order, while the greatest indirect effects were mainly realized through chest circumference and body length. Therefore, the most accurate regression model obtained for the female rabbits had chest circumference, body length and ear length in predicting the body weight. The path analysis for the male rabbits revealed that the direct effect of abdominal circumference and rump width on body weight were not statistically significant while the direct effect of nose to shoulder length and rump width on body weight, though statistically significant were negative. The positive, statistically direct effect on body weight was realized from chest circumference, body length, ear length, thigh circumference and tail length in that descending order. Therefore, the final regression model excluding redundant variables only had ear length, tail length, chest circumference, thigh circumference and body length for the male rabbits. Hence the body weight of male rabbits could be estimated with high degree of accuracy in the field using forecast indices such as chest circumference, body length and ear length for female rabbits and ear length, tail length, chest circumference, thigh circumference and body length for male rabbits. These morphometric traits could also guide selective breeding to improve meat production.

ACKNOWLEDGEMENT
The authors are grateful to the AFRICA-ai-JAPAN Project supported by the Japan International Corporation Agency (JICA) and the RPE-JKUAT for funding this project.

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