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Principal component analysis of body measurements and body indices and their correlation with body weight in Katjang does of Indonesia

Abstract

The present study was aimed to investigate the body measurements and body indices of Kacang do at Bone Bolango Regency of Indonesia. A total of 85 does (3years age) were recorded and analyzed by principal component analysis (PCA) to explain the body measurements and body indices. Eleven body measurements of face length (FL), face width (FW), face height (FH), ear length (EL), ear width (EW), body length (BL), withers height (WH), chest width (CW), chest depth (CD), chest girth (CG), cannon bone circumference (CC) and eleven body indices of cephalic index (CpI) length index (LI), depth index (DI), body index (BI), conformation index (CI), proportionality (Pr), relative depth of thorax (RDT), dactyl thorax index (DTI), thoracic development (TD), area index (AI), and relative cannon thickness index (RCTI) were calculated in this study. Four components of body measurements (FH, BL, CD, CG) and three components of body indices (CI, TD, RCTI) were identified as the first component (PC1) for Katjang does. The result suggests that the highly R2 value (0.61< R2<0.80) were obtained in linear regression of BW with CG (0.69) or PC1 (0.71) as predictors. The R2 value in linear regression of BW using body indices through PC1 and PC2 as predictors was showed moderate category (R2=0.72).

Keywords: body measurements, body indices, body weight, katjang does, PCA

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Introduction

Goats are important livestock in Indonesia because of their adaptation to harsh climates conditions, disease tolerance capacity and they can provide a full range of products for humans especially of meat production Total of goat population numbers in Indonesia at 2015 about 18,880,000 heads with total of meat production at 2015 about 65,900kg mean while, total of goat for slaughters at 2015 about 1,819,812 heads.[1] Bone Bolango Regency is located at Gorontalo Province (Sulawesi Island) that one of goat breeding tract in Gorontalo province. Total of goat population in Bone Bolango Regency at 2011 reached 5,872 heads and about 7.0% from total population at Gorontalo province.[1] The Katjang goat is a largest indigenous goat in Indonesia and used for meat production. Genetic improvement of indigenous livestock species is of importance because of their adaptation to harsh climatic condition and their disease tolerance capacity. The meat productions of Katjang bucks i.e. slaughters weight, carcass weight, carcass percentage and non carcass percentage were 25.56kg, 11.94kg, 46.80% and 53.20% respectively under feed ration containing soybean meal.[2] The litter size of Katjang does such were 2.95 kid/doe/year with kidding interval in the 1st, 2nd, 3rd, 4th, 5th and 6th parities were 271, 262, 243, 217, 223 and 239 days respectively.[3] Growth and development is important for production of meat animals. Body measurements are important parameters to describe growth. In addition to estimate body measurements and body indices can be described completely an individual or a population. Therefore, linear body measurements can be used as selection criteria for improvement of meat production in goat. Body conformation by recording of minimum body measurements which reduce the cost, labour and time is the need of the day. Body measurements in addition to weight measurements describes more completely an individual or population than do the conventional methods of weighing and grading. EAAP and FAO have used wither height for example as a prime indicator of grade.[4] Desirable body conformation, from the meat production viewpoint, is such a complex character that little progress has been made in reducing it to a single corporal measurement which can be taken on the live animal. Body indices from different body measurements, an objective assessment of body conformation from the standpoint of type may be relatively easier.[5] Combination of different linear measurements in the body indices may be more useful to describe the type and function of animal. A more reliable assessment of morpho metric relationship among livestock breed has been obtained using multivariate statistical tools such as principal component analysis.[6] Principal component analysis (PCA) is an interdependence technique whose primary purpose is to define the underlying structure among the variables under study. Though the number of components generated in PCA equals the number of variables in the study, first few components accounts for the highest proportion of the total variance. The PCA has been used as a tool in the assessment of the body conformation which can be conducted to understand of the complex growth process in the body dimensions of an animal during growth period. Results of principal component analysis not only impact the management of animals but also help in conservation and selection of multiple traits by breeders.[7] The PCA of body measurements in livestock were also used to explain body conformation in several livestock such as goat,[8–19] sheep,[6,12,20–25] cattle,[26–31] buffalo,[32] horse,[33] chicken[34] and rabbit.[13,14] Despite, previous study reported that the PCA of body measurements were also used to predict body weight in goat,[8–11] sheep[12] and rabbit.[13,14] This study was aimed at providing objective description of body measurements and body indices of Katjang does from Bone Bolango regency using principal component analysis (PCA). It also tested the hypothesis

that the relationships involving body weight and morphological traits may be different when body measurements derived from the PCA were used instead of the inter-correlated original morphological variables. The information obtained would be helpful to researchers and livestock producers with policies to assist conservation and sustainable utilization of the Katjang goat genetic resources by the proper use of morphological traits.

Materials and methods

Research site and animals

This research was conducted at Bone Bolango Regency, Gorontalo Province, Indonesia. This area is situated at latitude 000 18' 25" to 000 48' 21" N and longitude 1230 03' 41" to 1230 33' 06" E about 0 - 1500m above the sea level. The humidity 71.8 - 88.9 % with temperature 24.4 - 28.0 0C and rainfall occurring 38-378mm. Total of 85 animals (3pairs of permanent incisors) were measured for the principal component analysis (PCA) Body measurements and body weight. All animals were measured using measuring tape (butterfly, China) and measuring stick and taken based on previous studies.[6,18,19,25,31] Eleven body measurements were conducted on each goats such as face length (FL: measured from between the horn site/ poll to the lower lip), face width (FW: measured as the widest point of the head), face height (FH: measured from the poll to the jaw), ear length (EL: the distance from the base to the tip of the ear along the dorsal surface), ear width (EW: maximum distance at the middle of the ear), body length (BL: distance from the point of the shoulder to the pin bone), withers height (WH: vertical distance from ground to the point of withers measured vertically from the ridge between the shoulder bones to the fore hoof), chest width (CW: measured as a distance from left to right upper arm), chest depth (CD: the distance from the backbone at the shoulder to the brisket between the front legs), chest girth (CG: perimeter of the chest just behind the front legs and withers) and cannon bone circumference (CC: the smallest circumference of the cannon bone of foreleg). All body measurements were taken by technicians accredited by association. The scheme of body measurements in the Katjang doe was presented in Figure 1. Meanwhile, body weight of each animal was measured using hanging weight scale (CAMRY, China).

Body indices

Calculation of body indices were obtained according to previous studies[10,21,35] as follow:

Cephalic index (CpI)=(FW×100)/FL

Length index (LI)=BL/WH

Depth index (DI)=CD/WH

Body index (BI)=(BL/CG)×100

Conformation index (CI)=CG2/WH

Proportionality (Pr)=(WH/BL)×100

Relative depth of thorax (RDT)=(CD/WH)×100

Dactyl thorax index (DTI)=(CC/CG)×100

Thoracic development (TD)=CG/WH

Area index (AI)=WH×BL

Relative cannon thickness index (RCTI)=(CC/WH)×100

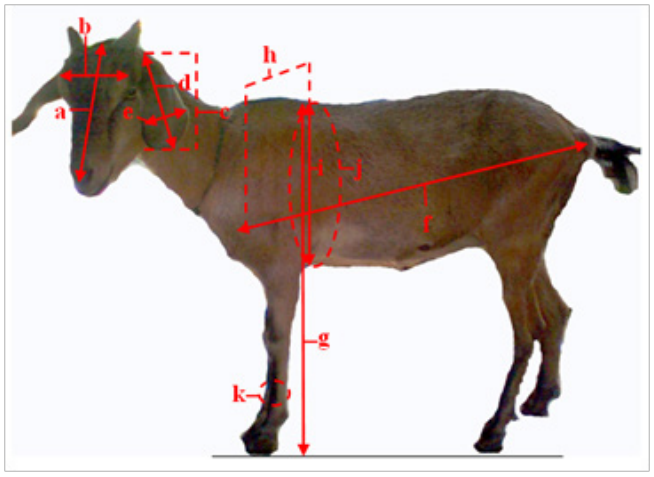

Figure 1 Scheme of body measurements in the Katjang doe consisted of face length (a), face width (b), face height (c), ear length (d), ear width (e), body length (f), withers height (g), chest width (h), chest depth (i), chest girth (j) and cannon bone circumference (k).

Statistical analysis

Data of body measurements and body indices were analyzed using Microsoft Office Excel 2007 computer program to describe mean, standard deviation (SD), coefficient of variation (CV) and minimum/maximum values. The phenotypic correlation (r) and the variance-covariance values were also determined. From the variance-covariance matrix, data for the PCA of body measurements and body indices were generated. The PCA equation as follows:[16]

$$PC_p = a_{1p}X_1 + a_{2p}X_2 + \ldots\ldots\ldots\ldots + a_{np}X_n$$

Where, PC_p is the pth principal component; anp is the nth vector Eigen of the pth principal component and X_n is the nth observed variables. Kaiser-Meyer-Olkin (KMO) test of sampling adequacy and Bartlett's test of sphericity were computed to establish the validity of the data set KMO's measure determines whether the common factor model is appropriate. The KMO should be greater than 0.50 for a satisfactory factor analysis to proceed. Rotation of principal components was through the transformation of the components to approximate a simple structure. The raw varimax criterion of the orthogonal rotation method was employed for the rotation of the factor matrix (the aim of the varimax rotation is to maximize the sum of variances of a quadratic weight). Cumulative proportion of variance criterion was finally employed to determine the number of components to extract. Simple and multiple linear regressions were performed in this study for identified the accuracy in each components when used as BW predictors. The linear regression equation as follows:[8]

$$BW = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_n X_n$$

$$BW = \beta_0 + \beta_1 PC_1 + \beta_2 PC_2 + \ldots\ldots\ldots + \beta_n PC_n$$

Where, BW is the body weigh; β_0 is the intercept; β_n is the regression coefficient, X_n is the nth observed variables and PC_n is the nth observed principal component. The tatistic analysis for principal component and regression analysis were performed using SPSS 16.0 computer program.

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Results and discussion

Body measurements and body weight

The descriptive statistics for all the body measurements was presented in Table 1 and the body measurements of several goat and sheep in the world was presented in Table 2. The moderate of CV value (0.10<CV<0.20) were obtained on measurements of FL, FW, EL, CW and BW. Therefore, the low of CV value (CV<0.10) were obtained on the other measurements. Body a measurement of WH and CG in Katjang does in the present study were higher than Malaysian Katjang (MK) does. However, BL in this study was lower than MK does (Table 2). Moreover, most of the body measurements of Katjang does in this study were highest than Black Bengal and West African Dwarf (WAD) does. According to the Table 2, body measurements of Katjang does in this study were lowest than several sheep breeds. The variation among breeds can be caused by the difference of genetic, nutrition, management system and climate.

Body indices

The descriptive statistics for all body indices was presented in Table 1. Moderate CV value were showed in body indices of CpI, CI, AI and FoL. Therefore, the lowly CV values were obtained on the other body indices. The body indices of Cuban Creole does were BI (85.29±5.57), CpI (63.65±3.49), Pr (93.19±3.77), RDT (47.66±1.42), DTI (9.58±0.50) and CI (97.01±3.96).[35] In addition, the body indices of Assam Hill does according to Khargharia et al. (2015) were LI (1.14±0.02), DI (0.51±0.01), BI (86.87±0.85), Pr (88.52±1.21), RDT (50.88±0.71) DTI (9.82±0.38), TD (1.32±0.02), AI (3355.13±48.84) and RCTI (12.95±0.14).[10] Meanwhile, the body indices of LI and DI were 1.01 and 0.53 respectively for WAD sheep and about 0.93 and 0.52 respectively for Yankasa sheep.[7] Body indices of BI, DTI and AI in the Katjang does in this study were higher than Assam Hill does. Thus, body indices of BI, Pr, DTI and CpI of Katjang does were higher than Cuban Creole does. According to BI value, the goat can be described three category such as brevigline (BI<0.85), medigline (0.86<BI<0.88) and longiland (BI >0.88). Moreover, according to DTI value, the goat can be described as four category such as light animals (DTI<10.5), intermediary (10.6<DTI<10.8), light meat animals (10.9<DTI<11.0) and heavy meat animals (11.1<DTI<11.5). Goats with TD more than 1.2 were included of good performance.[10,35] The Katjang does in this study can be described as light meat animals (DTI=10.24) and medigline animals (BI=86.95) with good of thoracic development (TD=1.24).

Phenotypic correlations

The phenotypic correlations (r) among body measurements and body indices were presented in Table 3 and Table 4 respectively. The highest r values were reached between CG and BW (0.83) and included of the very high category (0.80<r<1.00). Meanwhile, the highly r value (0.61<r< 0.80) among different body measurements were showed between FL-EW (0.62), EL-EW (0.63) and CC-CG (0.61). The highly r value were showed between BW and somebody indices of CI (0.69) and AI (0.64). Meanwhile, the highly r value among different body indices were showed between LI-TD (0.68), TD-DI (0.61), TD-Pr (0.67), TD-RDT (0.61) and RCTI (0.61). The strongly r value (0.81<r<1.00) were showed between LI-Pr (0.98), RDT-DI (0.99) and TD-CI (0.88). Previous studies reported that the highly r values between CG and BW were reported in some goat breeds of Assam Hill (0.79),[8] Pakistan commercial goat (0.76),[9] Atlas (0.91),[10] Barcha (0.77),[15] Black Bengal (0.85),[19] MK (0.88),[36] Red Sokoto (0.94),[38] WAD (0.91),[38] and 0.82 for Kilkecisi.[38] Despite, highly r values between CG and BW were reported in some sheep breeds such as Zulu (0.88),[7] Balami (0.80),[22] WAD (0.81),[24] Yankasa (0.85)[24] and 0.70 for Djallonke.[25] The r values of EL-EW, CD-EL and CD-EW in Kilkecisi does were 0.77; 0.32 and 0.25 respectively[37] and higher than Katjang does in the present study. Thus, the r value between DI and LI in WAD and Yankasa sheep's was 0.95 and 0.76 respectively7 and showed higher than Katjang does in the present study (0.57). Body measurement of CG in the Katjang does in this study can be influenced of BW because of highly correlation (r=0.83).

Principal component analysis

The communalities value, total variance explained by different components and rotated component matrix of different body measurements and body indices of Katjang does in this study were presented in Table 5, Table 6 and Table 7 respectively. The measure of sampling adequacy, Kaisee-Meyor-Olicn (KMO) of body measurements and body indices were 0.80 and 0.58 respectively. The overall significance of the correlations tested with Bertlett's test of Sphericity for the body measurements (Chi-squared was 362.32; p<0.01) and body indices (chi-squared was 2,113.00; p<0.01) were significant and provided enough support for the validity of the factor analysis of data. The communality values ranged from 0.44 (WH) to 0.81 (CG) for body measurements and 0.40 (CI) to 0.99 (BI) for body indices (Table 5) The screen plot of component number with eigen values for body measurements and body indices of Katjang does is given in Figure 2. There were three components extracted from different body measurements with Eigen values greater than 1.00 and accounted for 64.89% of total variance (Table 6).

Therefore, four components extracted from different body indices and accounted for 86.84% of total variance. The first (PC1), second (PC2) and third (PC3) components of body measurements were explained the does body about 41.31%, 13.71% and 9.87% of total variance respectively. Thus, PC_1; PC_2; PC_3; and PC_4 of body indices were explained does body about 41.50%, 16.36%, 15.71% and 13.28% of total variance respectively. According to Table 7, the negative assigned weight of different body measurements were found on PC_1 (FW) and PC_2 (CW and CD). Thus, the negative assigned weight of different body indices were found on PC_1 (CI, BI, Pr and DTI), PC_2 (CI, Pr and DTI), PC_3 (BI, CI, Pr, DTI and AI) and PC_4 (LI, DI, CI, RDT, TD and AI). Component plot of body measurements according to rotated component matrix is given in Figure 3. Three principal components of different body measurements was obtained in Katjang does and similar to Yankasa sheep6, Pakistan commercial goats,[9] Red Sokoto goats,[16] Nigerian indigenous goat,[18] Bargamesca ewes[20] and Balami sheep.[22] The communality value of CG in the present study was highest (0.81) than other measurements. Previous studies reported that the communality value of CG was highest than other body measurements in WAD does[8] Nigerian indigenous goat[18] and Zulu sheep.[24] All body measurements and body indices in PC_1 group were determined as the important measurements for goat selection.

Regression linear

Linear regression model of BW based on the original body measurements and body indices and their component score were presented in Table 8 and Table 9 respectively. According to Table 8, the highly coefficient of determination (R^2) value ($0.61<R^2<0.80$) were found in linear regression using CG as the independent variable

(R^2=0.69) and using FH, BL, CG and CD as the independent variables (R^2=0.71). Therefore, the R^2 value of simple linear regression with one component of PC_1 (0.63) was similar to R2 value of multiple linear regression with two components (PC_1, PC_2) or three components (PC_1, PC_2, PC_3). According to Table 9, the highly R^2 value was found in multiple linear regression with independent variables of CI, RCTI, TD and similar to the simple linear regression with variable of CG (R^2=0.69). Thus, the R^2 value of multiple linear regression with two components of PC_1 and PC_2 as independent variables was 0.72 and similar to R^2 value of multiple linear regression with three components (PC_1, PC_2, PC_3) or four components (PC_1, PC_2, PC_3, PC_4). Previous study showed that the R^2 values in simple linear regression of BW based on CG measurement in some goat/sheep were 0.55 (adult Zulu sheep),[8] 0.62 (Assam Hill does)[10] and 0.89 (Red Sokoto does).[24] Therefore, the R^2 value of simple linear regression with PC1 as independent variable in those breeds were 0.69 (adult Zulu sheep),[8] 0.64 (Assam Hill does)[10] and 0.63 for Red Sokoto does.[24] The prediction of BW based on principal component (PC) was more accurate than original body measurements.[24] However, the several study reported that prediction of BW based on PC were not accurate in Red Sokoto goat8, Pakistan commercial goat9 and Assam Hill does10. Prediction of BW in using original body measurements of PC_1 in this study was more appropriate (R^2=0.71) than the use of three principle components of body measurements (R^2=0.69). Therefore, prediction of body weight based on four elements of body indices was more appropriate (R^2=0.72) than the use of original body indices of PC_1 (R^2=0.69). The R^2 value in linear regression model 1 was highest than model 2, 3 (body measurements and body indices) and 4 (body indices) and suggested that all factors in PC_1 were important to explain the body of does in this study.

Table 1 Descriptive statistic of body measurements and body indices of Katjang does of Indonesia.

Parameter	Mean	SD	CV (%)	Min.	Max.
Body measurements (cm)					
Face length	14.12	1.45	10.29	10	19
Face width	10.94	1.31	12.01	8.5	16
Face height	12.31	1.04	8.41	10.5	15
Ear length	14.86	1.68	11.28	12	19
Ear width	7.12	0.68	9.51	5.9	9
Body length	60.26	4.27	7.08	49.6	69.7
Withers height	56.26	3.84	6.83	49	68
Chest width	15.33	1.93	12.61	10	20
Chest depth	25.97	1.98	7.64	18.5	30
Chest girth	69.42	4.64	6.69	58	81
Cannon bone circumference	7.1	0.64	8.99	6	9
Body weight (kg)	27.11	4.93	18.18	17	42
Body indices					
Cephalic index	77.91	10.01	12.85	63.33	133.33
Length index	1.07	0.09	8.28	0.75	1.34
Depth index	0.46	0.04	8.79	0.31	0.56
Body index	86.95	5.4	6.21	73.61	102.24
Conformation index	86.06	10.25	11.92	63.47	115.57
Proportionality	93.71	8.15	8.7	74.37	133.33
Relative depth of thorax	46.32	4.07	8.79	31.15	55.77
Dactyl thorax index	10.24	0.73	7.14	8.57	11.94
Thoracic development	1.24	0.09	6.97	0.99	1.5
Area index	3394.46	379.2	11.17	2430.4	4596.8
Relative cannon thickness index	12.64	1.08	8.56	10.34	15.84

N, number of observation; SD, standard deviation; CV, coefficient of variation; Min, minimum value; Max, maximum value

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Table 2 The Means of body measurements in several breeds of adult goat and sheep in the world.

Species / Breeds	Sex	BW	FL	FW	EL	EW	BL	WH	CW	CD	CG	CC	Reference
Goat													
Malaysian Katjang	Female	23.65	14.58	11.91	13.27	-	70.5	50.21	-	-	63.46	-	(36)
Cuban Creole	Female	-	17.71	11.24	12.68	-	65.54	60.97	16.36	-	76.87	7.36	(35)
Assam Hill	Female	24.86	-	-	-	-	61.48	54.57	-	27.68	71.93	7.71	(10)
Andalusian White	Female	-	22.46	13.65	-	-	80.25	73.64	-	33.55	89.85	9.87	(38)
Florida	Female	-	25.54	12.78	-	-	80.54	77.91	-	34.79	90.92	9.24	(38)
Granada	Female	-	18.53	12.4	-	-	73.97	68.22	-	30.98	85.59	7.97	(38)
Malaga	Female	-	17.94	12.84	-	-	71.64	69.44	-	30.97	87.52	8.72	(38)
Andalusian Black	Female	-	22.39	13.67	-	-	81.25	76.98	-	35.01	96.24	9.96	(38)
West African Dwarf	Overall	17.14	-	9.41	-	-	45.1	44.09	10.81	26.43	60.09	-	(16)
Red Sokoto	Overall	22.32	-	12.13	-	-	51.63	62.34	14.24	31.42	69.81	-	(16)
Barcha	Female	36.9	24	-	21	8.8	98.7	71.4	-	-	74.7	-	(19)
Atlas	Female	38.3	24	-	20.5	8.54	99.5	71.6	-	-	75.6	-	(19)
Black Bengal	Female	12.4	15.1	10.55	11.9	-	42.15	43.1	-	-	53.4	-	(15)
Kilkecisi	Female	51.2	22.7	11.3	16.9	8	80.6	74.8	17.7	32.9	86.8	9.7	(37)
Norduz	Female	-	41.32	-	-	-	67.63	65.64	22.34	31.44	89.43	-	(39)
Honamli	Female	63.5	-	-	-	-	88.3	83	-	-	91	-	(40)
Sheep													
Djallonke	Female	-	-	-	-	-	54.87	57.06	-	25.66	65.19	-	(25)
Yankasa	Overall	41.6	-	-	-	-	70.9	76.16	15.08	-	86.63	-	(7)
Uda	Overall	-	21.47	-	-	-	59.37	65.83	14.4	-	71.98	-	(21)
Assaf	Female	75.74	31.11	14.52	17.9	10.33	-	-	26.85	-	-	-	(23)
Balami	Overall	53.01	-	-	-	-	96.06	83.96	27.85	-	95.05	-	(22)
Zulu	Female	33.39	18.84	10.86	9.51	-	63.82	63.18	-	32.7	79.26	9.3	(24)
Bergamasca	Female	-	-	-	-	-	78.3	79.5	23.8	-	99	-	(20)
Dombos	Female	-	-	-	-	-	61.89	63.14	22.1	30.47	93.65	-	(41)

FL, face length; FW, face width; EL, ear length; EW, ear width; BL, body length; WH, withers height; CW, chest width; CD, chest depth; CG, chest girth; CC, cannon bone circumference

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Table 3 Phenotypic correlation between body weight and body measurements in Katjang does of Indonesia.

Variables*	BW	FL	FW	FH	EL	EW	BL	WH	CW	CD	CG	CC
Body weight (BW)	1	0.55	0.15	0.59	0.25	0.38	0.56	0.43	0.31	0.38	0.83	0.56
Face length (FL)	-	1	0.39	0.42	0.43	0.62	0.45	0.42	0.24	0.25	0.58	0.59
Face width (FW)	-	-	1	0.20^{ns}	0.18^{ns}	0.3	0.17^{ns}	0.27	0.24	0.07^{ns}	0.23	0.49
Face height (FH)	-	-	-	1	0.24	0.29	0.41	0.37	0.27	0.3	0.58	0.3
Ear length (EL)	-	-	-	-	1	0.63	0.29	0.24	0.03^{ns}	-0.02^{ns}	0.21	0.35
Ear width (EW)	-	-	-	-	-	1	0.45	0.42	0.19	0.02^{ns}	0.44	0.45
Body length (BL)	-	-	-	-	-	-	1	0.27	0.2	0.41	0.6	0.38
Withers height (WH)	-	-	-	-	-	-	-	1	0.31	0.25	0.46	0.45
Chest width (CW)	-	-	-	-	-	-	-	-	1	0.29	0.5	0.3
Chest depth (CD)	-	-	-	-	-	-	-	-	-	1	0.48	0.17^{ns}
Chest girth (CG)	-	-	-	-	-	-	-	-	-	-	1	0.61
Cannon bone circumference (CC)	-	-	-	-	-	-	-	-	-	-	-	1

*(P<0.05); ns(P>0.05)

Table 4 Phenotypic correlation between body weight and body indices in Katjang does of Indonesia.

Body indices*	BW	CpI	LI	DI	BI	CI	Pr	RDT	DTI	TD	AI	RCTI
Body weight (BW)	1	-0.22	0.13^{ns}	0.01^{ns}	-0.25	0.69	-0.14^{ns}	0.02^{ns}	-0.06^{ns}	0.38	0.64	0.26
Cephalic index (CpI)	-	1	-0.10^{ns}	-0.02^{ns}	0.01^{ns}	-0.17^{ns}	0.10^{ns}	-0.03^{ns}	0.27	-0.12^{ns}	-0.12^{ns}	0.12^{ns}
Length index (LI)	-	-	1	0.57	0.59	0.47	-0.98	0.59	-0.16^{ns}	0.68	0.05^{ns}	0.43
Depth index (DI)	-	-	-	1	0.10^{ns}	0.4	-0.55	0.99	-0.28	0.61	-0.24	0.26
Body index (BI)	-	-	-	-	1	-0.33	-0.58	0.11^{ns}	0.06^{ns}	-0.19	0.2	-0.09^{ns}
Conformation index (CI)	-	-	-	-	-	1	-0.48	0.41	-0.25	0.88	0.3	0.51
Proportionality (Pr)	-	-	-	-	-	-	1	-0.56	0.21	-0.67	-0.06^{ns}	-0.4
Relative depth of thorax (RDT)	-	-	-	-	-	-	-	1	-0.28	0.61	-0.23	0.26
Dactyl thorax index (DTI)	-	-	-	-	-	-	-	-	1	-0.27	0.01^{ns}	0.61
Thoracic development (TD)	-	-	-	-	-	-	-	-	-	1	-0.12^{ns}	0.6
Area index (AI)	-	-	-	-	-	-	-	-	-	-	1	-0.09^{ns}
Relative cannon thickness index (RCTI)	-	-	-	-	-	-	-	-	-	-	-	1

*(P<0.05); ns(P>0.05)

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Table 5 Communalities value of different body measurements and body indices in Katjang does of Indonesia.

Parameter	Initial	Extraction
Body measurements		
Face length	1	0.673
Face width	1	0.702
Face height	1	0.529
Ear length	1	0.729
Ear width	1	0.772
Body length	1	0.627
Withers height	1	0.437
Chest width	1	0.556
Chest depth	1	0.632
Chest girth	1	0.806
Cannon bone circumference	1	0.675
Body indices		
Cephalic index	1	0.398
Length index	1	0.968
Depth index	1	0.866
Body index	1	0.996
Conformation index	1	0.966
Proportionality	1	0.944
Relative depth of thorax	1	0.869
Dactyl thorax index	1	0.899
Thoracic development	1	0.953
Area index	1	0.723
Relative cannon thickness index	1	0.969

Table 6 Total variance explained by different components of body measurements and body indices in Katjang does of Indonesia.

Group/ Component	Initial eigen values			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
Body measurements									
1	4.544	41.31	41.31	4.544	41.31	41.31	2.626	23.876	23.876
2	1.508	13.71	55.02	1.508	13.71	55.02	2.388	21.706	45.582
3	1.086	9.873	64.893	1.086	9.873	64.893	2.124	19.311	64.893
4	0.771	7.005	71.898	-	-	-	-	-	-
5	0.65	5.913	77.812	-	-	-	-	-	-
6	0.616	5.596	83.407	-	-	-	-	-	-
7	0.526	4.783	88.191	-	-	-	-	-	-
8	0.464	4.22	92.411	-	-	-	-	-	-
9	0.416	3.786	96.197	-	-	-	-	-	-
10	0.246	2.24	98.437	-	-	-	-	-	-
11	0.172	1.563	100	-	-	-	-	-	-

Table Continued

Group/ Component	Initial eigen values			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
Body indices									
1	4.565	41.501	41.501	4.565	41.501	41.501	3.187	28.977	28.977
2	1.799	16.355	57.856	1.799	16.355	57.856	2.651	24.104	53.081
3	1.728	15.706	73.562	1.728	15.706	73.562	1.968	17.894	70.975
4	1.46	13.277	86.839	1.46	13.277	86.839	1.745	15.865	86.839
5	0.816	7.416	94.255	-	-	-	-	-	-
6	0.607	5.52	99.776	-	-	-	-	-	-
7	0.017	0.151	99.926	-	-	-	-	-	-
8	0.003	0.03	99.957	-	-	-	-	-	-
9	0.002	0.019	99.976	-	-	-	-	-	-
10	0.001	0.012	99.989	-	-	-	-	-	-
11	0.001	0.011	100	-	-	-	-	-	-

Table 7 Rotated component matrix of different factors for body measurements and body indices in Katjang does of Indonesia.

Parameter	Principal component			
	1	2	3	4
Body measurements				
Face length[2]	0.36	0.595	0.435	-
Face width[3]	-0.102	0.163	0.815	-
Face height[1]	0.666	0.278	0.092	-
Ear length[2]	0.017	0.853	0.043	-
Ear width[2]	0.16	0.819	0.275	-
Body length[1]	0.667	0.424	0.041	-
Withers height[3]	0.363	0.272	0.481	-
Chest width[3]	0.437	-0.18	0.577	-
Chest depth[1]	0.775	-0.164	0.074	-
Chest girth[1]	0.766	0.249	0.396	-
Cannon bone circumferance[3]	0.248	0.396	0.676	-
Body indices				
Cephalic index[4]	-0.0198	-0.03	0.236	0.55
Length index[2]	0.471	0.845	0.175	-0.028
Depth index[3]	0.408	0.364	0.737	-0.157
Body index[2]	-0.363	0.922	-0.112	0.052
Conformation index[1]	0.964	0.044	-0.05	-0.181
Proportionality[3]	-0.466	-0.835	-0.161	0.063
Relative depth of thorax[3]	0.413	0.38	0.728	-0.155
Dactyl thorax index[4]	-0.056	-0.045	-0.239	0.915
Thoracic development[1]	0.899	0.194	0.317	-0.085
Area index[3]	0.16	0.224	-0.78	-0.197
Relative cannon thickness index[1]	0.69	0.141	0.049	0.686

[1,2,3,4]elements of the each component

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Table 8 Linear regression model of body weight on original body measurements (PC1) and their component score.

Model	Prediction equation	R^2	SE
	Original body measurements as predictors		
1	BW=2.80 (FH)-7.34	0.35	4.01
2	BW=0.65 (BL)-12.05	0.32	4.1
3	BW=0.95 (CD)-2.34	0.15	4.58
4	BW=0.88 (CG)-34.10	0.69	2.76
5	BW=0.72 (FH)+0.11 (BL)+0.75 (CG)-0.10 (CD)-37.79	0.71	2.71
	Principal components as predictors		
1	BW=0.43 PC_1-43.74	0.63	3.05
2	BW=0.003 PC_2-4.00	0.6	3.14
3	BW=0.65 PC_3-0.52	0.52	3.44
4	BW=0.32 PC_1+0.001 PC_2-29.94	0.63	3.04
5	BW=0.32 PC_1+0.001 PC_2+0.008 PC_3-30.17	0.63	3.06

BW, body weight; FH, face height; BL, body length; CD, chest depth; CG, chest girth; PC, principal component; R2, coefficient of determination; SE, standard error

Table 9 Linear regression model of body weight on original body indices (PC1) and their component score.

Model	Prediction equation	R^2	SE
	Original body indices as predictors		
1	BW=0.33 (CI)-1.29	0.47	3.6
2	BW=21.77 (TD)+0.16	0.15	4.58
3	BW=1.19 (RCTI)+12.09	0.07	4.79
4	BW=0.73 (CI)+0.38 (RCTI)-57.26 (TD)+30.16	0.69	2.82
	Principal components as predictors		
1	BW=0.06 PC_1-3.90	0.53	3.42
2	BW=0.04 PC_2-0.57	0.39	3.88
3	BW= -0.01 PC_3-0.50	0.4	3.83
4	BW=1.26-0.04 PC4	0.42	3.79
5	BW=0.22 PC_1-0.13 PC_2+1.43	0.72	2.66
6	BW=0.22 PC_1-0.13 PC_2-0.01 PC_3+1.45	0.72	2.67
7	BW=0.22 PC_1-0.13 PC_2-0.01 PC_3+0.03 PC_4-0.10	0.72	2.68

BW, body weight; FH, face height; BL, body length; CD, chest depth; CG, chest girth; PC, principal component; R2, coefficient of determination; SE, standard error

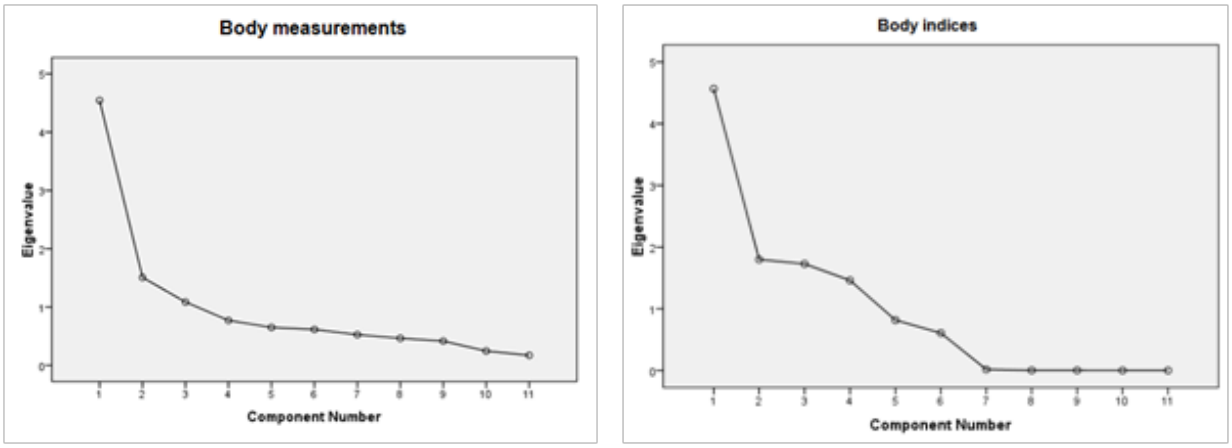

Figure 2 Scree plot showing component number with eigenvalues for body measurements and body indices in Katjang does of Indonesia.

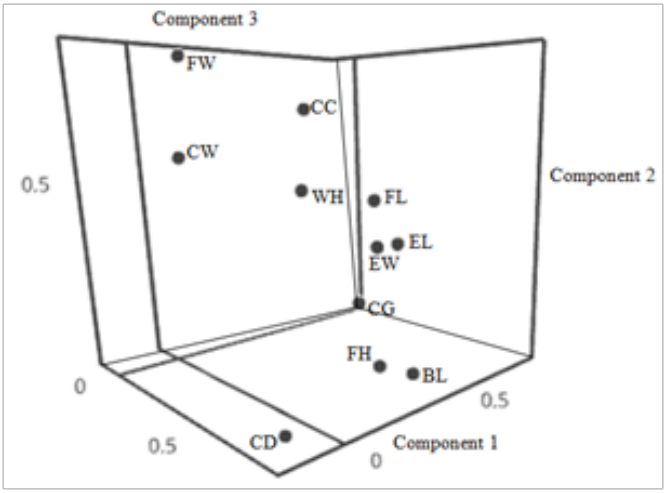

Figure 3 Component plot of body measurements in the Katjang does in rotate space consisted of face length (FL), face width (FW), face height (FH), ear length (EL), ear width (EW), body length (BL), withers height (WH), chest width (CW), chest depth (CD), chest girth (CG) and cannon bone circumference (CC).

Conclusion

The principal component analysis (PCA) for body measurements and body indices in the present study can be used to predict body weight of Katjang does. The PC1 of body measurements can be used for body weight prediction in Katjang does with R2=0.63. Moreover, the PC1 and PC2 of body indices were more accurate for body weight prediction with R2=0.72. Further research with large number of sample is important to get the accurate formula for body weight prediction of Katjang goat in the future.

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Conflicts of interest

The author declares that there no conflicts of interest.

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