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Morphology and morphometric diversity of three local goats in Gorontalo, Indonesia

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Abstract. *Ilham F, Ciptadi G, Susilorini TE, Putra WPB, Suyadi S. 2023. Morphology and morphometric diversity of three local goats in Gorontalo, Indonesia. Biodiversitas 24: 1366-1375.* This research aimed to identify morphology and morphometric, as well as body indices and measurements markers, for use in local goats selection program in Gorontalo, Indonesia. The samples consisted of 37 Etawah Crossbreed, 96 Local Gorontalo, and 40 Kacang goats raised by traditional semi-intensive breeders. The morphological variables observed included feather color, color combination pattern, nose, ear shape, horn, beard, tail direction, and morphometric variables observed were withers height, hip height, hip width, body length, chest width, chest depth, chest girth, ear length, and ear width. The qualitative morphology was analyzed with descriptive method with Chi-squared test. While, the morphometrics of goat was used for calculating the body indices and principal component analysis. The results of the chi-square analysis showed significant differences in qualitative morphology among the three observed breeds ($p<0.05$), except for the presence of horns, beards, and the direction of the tail. The body measurements of Local Gorontalo goats were significantly different from those of Kacang goats except for chest depth. The only difference between the Etawah Crossbreed and the other two breeds included body weight, wither height, hip height, body length, ear length, and ear width ($p<0.05$). The three local goats had a long body length and legs, with a waist higher than the shoulders. Meanwhile, the medigline classification was only for Local Gorontalo and Kacang goats that had good thoracic development. The conformation index of the three local goat breeds had a significant correlation with body weight. The variables with the best contribution from the first component that can be considered sequentially in the selection program for Etawah Crossbreed goats, Local Gorontalo, and Kacang goats were body length, chest girth, and wither high. For the second component, the variables included ear length and chest width, while that of the third component in Kacang goats was ear length.

Keywords: Body indices**,** correlation, diversity, local goats, principal component, selection

INTRODUCTION

In 2020, Indonesia had a goat population of 19.096.381 (BPS-Statistics Indonesia 2021), accounting for 50.14% of the total 37.844.420 goats in Southeast Asia (FAO 2019), dominated by indigenous (Kacang) and local breeds. These local goats are the results of cross-breeding between the indigenous goats and exotic goat breeds such as Etawah, Boer, and Saanen goat from India, Africa, and Switzerland, respectively, which have been bred for more than five generations (Government Regulation of the Republic of Indonesia Number 48 2011).

The Etawah is called Jamunapari, the Pari or Angel in India, and is considered the best milk-producing breed (Hassan et al. 2010; Talukder and Choudhury 2018). The spread of the Etawah to Europe and America has produced the offspring of dairy goats of Anglo-Nubian and American-Nubian (Rout et al. 2012, Ángel-sahagún et al. 2021). In Indonesia, various breeds of goats have been developed, including Etawah Crossbreed, Saanen-Etawah (Sapera), Boer-Etawah (Boerawa)/Saburai, Senduro, and Kaligesing (Sutopo et al. 2018; Ciptadi et al. 2019; Dagong et al. 2019; Hardyta et al. 2020; Prastiya et al. 2021). The Etawah Crossbreed goat is the result of crossbreeding the Indonesian Kacang goats, which is known for its small, morphometric body compared to the larger Indian Etawah/Jamunapari (Mudawamah et al. 2021; Suyadi et al. 2021). The Etawah Crossbreed goat has received legitimacy from the Government of Indonesia as a special family of local livestock, along with others, such as Senduro, Boerka Galaxy Agrinak, Gembrong, Kaligesing, Kejobong, and Saburai goats (Directorate of Livestock Breeding and Production 2020).

Several local breeds are still in the identification and characterization stage, particularly phenotypic and genetic characteristics, to obtain the legitimacy of the local livestock family from the Government of Indonesia. Although Etawah Crossbreed goats have spread in many provinces, they only display maximum performance in a lush environment and sufficient food resources (Sumartono et al. 2016). This has limited traditional goat breeders with little production capital to raise the Etawah Crossbreed, leading to cross-breed with Kacang goats to produce offspring of several breeds (Rahmawati et al. 2022). The offspring from crosses with Etawah Crossbreed that resembles Kacang goats is known as Jawarandu goats (Zein

et al. 2012). Crossbreeding between Etawah Crossbreed and Kacang goats in Gorontalo has produced Local Gorontalo goats that have adapted well to local environmental conditions. Traditional farmers in rural areas widely cultivate the offspring from these crosses because they are more adaptive and provide support for the family economy. As of 2021, local goats' population in Gorontalo was 106,090 (BPS-Statistics Indonesia 2021)

The high body weight and measurement diversity are a problem in local goat farming. This has led to the demand for a selection process to improve the genetic quality of the offspring and the economic value of goats (Lopes et al. 2012). Currently, morphometric-based selection remained popular among rural farmers due to its practicality and economic value compared to the molecular approach. Besides describing the quality of livestock growth and phenotypic description (Praharani et al. 2019), it can also be used as selection criteria to increase goat meat production (Putra and Ilham 2019). Furthermore, morphometric is applicable in the calculation of body indices of each individual to identify their type, talent, and production ability (Macedo 2017; Getaneh et al. 2022). One commonly used method for selection based on livestock morphometric is Principal Component Analysis. This method is applied to reduce several variables that can be used as selection criteria, such as in Malabari (Valsalan et al. 2020), native goats in Nigeria (Shoyombo et al. 2015; Iyiola-Tunji et al. 2016), and local goats in Indonesia (Kurnianto et al. 2013). Therefore, this research aims to identify morphology and morphometric diversity of local goats in Gorontalo, classify local goats based on body indices, and obtain phenotypic markers using principal component analysis. The description of body weight and body measurements of Local Gorontalo goats have been reported in many previous studies. Currently, the body indices and principal component analysis are not reported previously. The results are expected to form the basis for strategic characterization, conservation, and selection specifically for local goat breeding programs in Indonesia.

MATERIALS AND METHODS

Research area

Morphology and morphometric data were collected in Gorontalo Province, specifically in Bone Bolango and Gorontalo Districts, covering a total area of 4.040,92 km^2 (Figure 1). The locations in the two districts are at an altitude of <100 meters above sea level, with an average air humidity of 77.8%, a temperature of 27.14°C, a precipitation rate of 92.13 mm, a daily rainfall rate of 9.24 days/month, and sunlight at 66.29%. The breeding system was traditional semi-intensive or simple cages, where some farmers allowed their livestock to search for their feed from morning to evening. There was no designated land for goats grazing, and the type, as well as the amount of feed given, were not fixed. The common feed types included natural grass, *Lamtoro* leaves (*Leucaena leucocephala*), goats wood (*Garuga floribunda*), Javanese wood leaves (*Lannea coromandelica*), *Kelumpang* leaves (*Sterculia foetida*), Jackfruit leaves *(Artocarpus heterophyllus)*, rice/corn bran, and kitchen leftovers/vegetables.

A total of 173 goats from 37 Etawah Crossbreeds, 96 Local Gorontalo, and 40 Kacang goats were used in this research. The age of goats was identified by observing the changes of milk incisors to permanent teeth, with criteria ranging from ≥3 months to 1 year (I_0), 1 to 1.5 years (I_1), 1.5 to 2.5 years (I_2), 2.5 to 3.5 years (I_3), and I_4 for ≥3.5 (I_4) (Sulastri and Sumadi 2012).

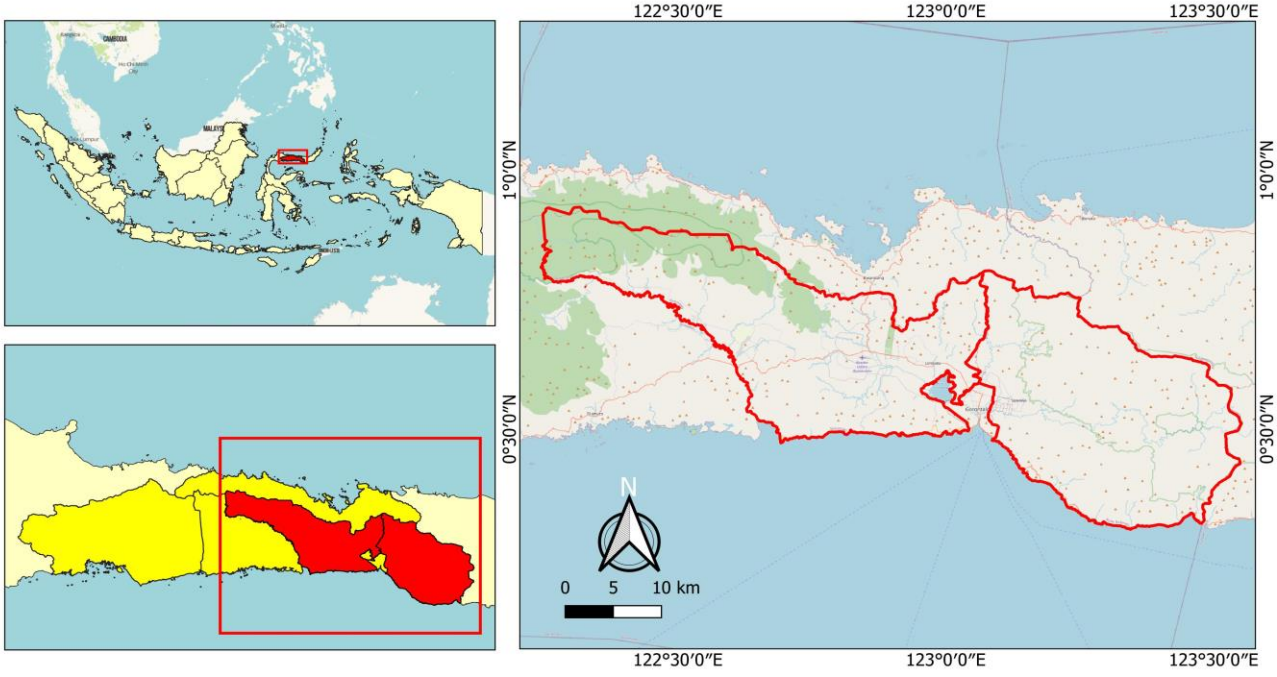


Figure 1. Research area for local Gorontalo goat in Bone Bolango and Gorontalo Districts, Indonesia

The observed morphological variables were feather color dominant, color combination pattern, nose profile, ear shape, horn, beard, and tail direction. Meanwhile, the observed morphometric variables included body weight, withers height (vertical distance from the ground to the point of withers measured vertically from the ridge between the shoulder bones to the fore hoof), hip height (vertical distance from the ground to the point of hip), body length (distance from the point of the shoulder to the pin bone), chest width (measured as a distance from left to the right upper arm), chest depth (the distance from the backbone at the shoulder to the brisket between the front legs), and chest girth (perimeter of the chest just behind the front legs and withers) ear length (the distance from the base to the tip of the ear along the dorsal surface), and ear width (maximum distance at the middle of the ear) (Khargharia et al. 2015; Dea et al. 2019; Putra and Ilham 2019).

The samples observed were livestock goats reared in a semi-intensive traditional approach. Purposive and incidental sampling techniques were used to collect observational samples. Subsequently, all Local Gorontalo goats were from the research site and had different morphologies from the other two groups. Kacang goats and Etawah Crossbreed goats were selected based on criteria from the Indonesian Ministry of Agriculture and the Indonesian National Standards Agency (SNI) No 7325:2008. The body weight (kg) and morphometric (cm) measurements were taken using a digital hanging scale (model WH-C100 micro crane scale), a 1-meter measuring stick (Joyko brand), and a body measuring tape (Agrotech brand).

Statistical analysis

The description of morphology, body weight, and body measurements was calculated based on descriptive statistical analysis, including the mean and Standard Deviation (SD). The data on body weight and measurements were standardized to adult age (I_4) and female sex using a correction factor (Rusdin et al. 2018).

Body indices were examined to determine whether Local Gorontalo goats have a proportional body shape. The formula used was length index = body length/withers height, depth index = chest depth/withers height, body index = (body length/chest girth)×100 conformation, body ratio = height at withers/rumps' height, conformation index = chest girth^2/withers' height, proportionality = (withers height/body length)×100, the relative depth of thorax = (chest depth/withers height)×100, thoracic development = chest girth/withers height, area index = withers height × body length, foreleg length index = withers height' chest depth, height slope index (HSI) = Rump height' height at withers, body weight = 0.88 (CG)-34.10 (Chacón et al. 2011; Khargharia et al. 2015; Putra and Ilham 2019).

A Chi-square test was conducted to compare morphologies between Etawah Crossbreed, Local Gorontalo, and Kacang goats breeds. A Multivariate Analysis of Variance (Manova) with a univariate General Linear Model (GLM) procedure was employed to distinguish the body weight and body measurements of the three breeds. When the significance value of <0.05 was obtained, a further test (post hoc) Bonferroni was carried out for equal variance or the Games-Howell test for different variances.

The Pearson correlation analysis was used to determine the significance of the relationship between body weight and body index. Principal Component Analysis (PCA) was applied to assess body measurements as a marker for selection of local goats. PCA was used to reduce body measurement variables into uncorrelated main components, which can be used as identifying factors in selection program. The feasibility of the data before PCA analysis was known based on the value of the Kaiser-Meyer-Olkin Measure (KMO) test and Bartlett's Test of Sphericity. The statistical tool used to make calculations easier was the SPSS statistical software 16.

RESULTS AND DISCUSSION

Morphology qualitative description

The qualitative morphology of Local Gorontalo goats was different from that of Etawah Crossbreed and Kacang goats ($p<0.05$), except for the horns and beard, as illustrated in Table 1. Furthermore, the dominant color on the body was brown, with a proportion of 38.1% and the most color combinations were brown and white, namely 28.9%. The nose profile was mostly convex (90.7%), similar to Etawah Crossbreed but very different from Kacang goats, which was 100% flat. Ear shape was mostly half dangle with values of 47.4%, while the Etawah Crossbreed goats were 100% drooping and Kacang goats were 100% straight sideways/upwards. The three goat breeds mostly have short/long horns, no beard, and a tail pointing backward (Figure 2). Based on these results, the differences in the percentages of all qualitative morphology in Table 1 included the ear shape and nose profile, which can be used to distinguish the three breeds.

Qualitative performance has little effect on productivity but it is essential as an identifier of the herd or type of livestock. Although qualitative performance is not dominant compared to quantitative, it also determines the selling price of goats in several countries. Despite being in different environments, it tends to be more stable due to the influence of a few genetic and environmental factors. As shown in Table 1, the distribution and frequency of coat color of Local Gorontalo goats were more varied than Etawah Crossbreed and Kacang goats, indicating an undirected crossbreeding pattern in local goats' populations in Gorontalo, Indonesia. The color and other qualitative characteristics of some Local Gorontalo goats were insignificantly different from those of several goat breeds from other regions in the country. Bligon goats from crosses between Etawah Crossbreed and Kacang goats in the lowland district of Bantul, Yogyakarta also have striped body coat colors of 39.6%, white 32.7%, black 18.9%, and brown 8.8% (Rahmawati et al. 2022). The color of the coat on the goat's body can affect its ability to regulate and adapt to extreme weather. This is because animals with black fur absorb the heat from the sun more quickly but

with slow reflection. Therefore, they are susceptible to heat stress, but it helps to keep the animals warm in the winter (Hagan et al. 2012; Ofori et al. 2021).

Body weight and body measurements description

The data in Table 2 showed the body weight and body measurements of Local Gorontalo with adult Etawah Crossbreed and Kacang goats. The weight and overall body measurements of Local Gorontalo differed from Kacang goats, except for their chest depth. Compared to Etawah Crossbreeds, body weight, wither height, hip height, body length, ear length, and ear width were significantly different ($p<0.05$). However, the hip width, chest width, chest depth, and chest girth were not significantly different ($p>0.05$).

The average body weight of Local Gorontalo goats was higher than those of Kacang, with 27.1±4.9 kg (Putra and Ilham 2019) but lower than the 41.7±7 kg of the Etawah crossbreed (*Badan Standardisasi Nasional Indonesia* 2008). Previous investigations of local goats in Indonesia showed that body weight was almost the same as Gorontalo local goats such as Senduro goats 46.7±10.2 kg (Directorate of Livestock Breeding and Production 2020), Jawarandu 45.5±6.5 kg (Kurnianto et al. 2013), Bligon 39.5±10.0 kg (Rahmawati et al. 2022), Kejobong 36.9±5.6 kg (Kurnianto et al. 2013), Sapera 36 kg (Rusdiana et al. 2016), and Saburai 33.8±6.1 kg (Directorate of Livestock Breeding and Production 2020). The description of Local Gorontalo goats above is an area with potential development and an alternative for traditional breeders with low production capital to develop Etawah Crossbreed goats. However, body weight and variation in most of the body measurement coefficient values are still relatively high compared to cross-breed Etawah Crossbreed and Kacang goats, making selection process necessary. The research on Philippine Native, Upgraded, Anglo-Nubian, Boer, and Saanen goats in the Philippines also showed variations in qualitative and quantitative phenotypic characteristics (Malvaz 2019). This can be due to the influence of genetic factors on weight and body measurement variations between goat breeds, feed consumed, rearing management, and climate (Putra and Ilham 2019). The growth of goats must also be considered because it is influenced by additive genetic factors, parents, and the environment (Dige et al. 2021). Meanwhile, adequate feeding and management of goats can significantly support production and reproduction performance (Bhowmik et al. 2014). The assessment of diversity is essential to improve the breeding and industrial development of local goats' populations in the future (Guang-Xin et al. 2019).

Body indices description

The measurement of livestock body indices is often used to describe the size and proportion of the livestock (Khargharia et al. 2015). In selection process, the use of body indices can produce more accurate values compared to measurements with a single morphometric trait, It also provides information on an animal's productive abilities and talents (Macedo 2017). The analysis results in Table 3 showed that there were significant differences in body indices variables between the three goat breeds observed ($p<0.05$), except for length index and proportionality ($P>0.05$). Research on Cuban Creole and cross-breed goats also gave significant differences in body index, proportionality, conformation index/baron and crevat, and length index/relative body index (Chacón et al. 2011).

Table 1. Qualitative morphology of Etawah Crossbreed, Local Gorontalo, and Kacang goats

Morphology qualitative	Breed			Sig.
	Etawah Crossbreed (%)	Local Gorontalo (%)	Kacang goats (%)	
Feather color dominant				0.0
Black	0.00	24.7	40.9	
White	100	37.1	22.7	
Brown	0.00	38.1	36.4	
Color combination pattern				0.0
Full black	0.0	10.3	31.8	
Full white	3.0	2.1	0.0	
Full brown	0.0	6.2	4.5	
Black and White	78.8	26.8	25.0	
Black and Brown	3.0	11.3	25.0	
Black white brown	5.0	14.4	11.4	
Brown and White	15.2	28.9	6.8	
Nose Profile				0.0
Convex	100	90.7	6.8	
Flat	0.0	9.3	93.2	
Ear shape				0.0
Straight sideways/upwards	0.0	10.3	100	
half dangle	0.0	47.4	0.0	
dangle down	0.0	27.8	4.5	
Drooping	100	14.4	0.0	
Horn				0.34
Horn	97.0	95.3	100	
No horn	3.0	4.7	0.0	
Beard				0.92
Bearded	6.1	8.2	6.8	
No beard	93.9	91.8	93.2	
Tail direction				
To the back	100	100	100	

Figure 2. Morphological characteristics of Indonesian goat. A-B. Etawah Crossbreed. C-D. Local Gorontalo. E-F. Kacang goats. The differences in morphology between the three local goats breeds are visible in the dominant coat color, ear shape, and nose profile

Table 2. Description of body weight and body measurements of Etawah Crossbreed, Local Gorontalo, and Kacang goats breeds of Indonesia

Variable	Etawah Crossbreed		Local Gorontalo		Kacang goats	
	Mean±SD	CV (%)	Mean±SD	CV (%)	Mean±SD	CV (%)
Body weight (kg)	44.72±7.73^{c}	17.28	37.49±9.53^{b}	25.42	29.87±5.58^{a}	18.76
Wither height (cm)	72.53±4.60^{c}	8.66	64.72±6.78^{b}	10.48	58.71±4.95^{a}	6.34
Hip height (cm)	76.71±4.10^{c}	7.59	66.31±7.29^{b}	10.99	59.67±4.35^{a}	7.29
Hip width (cm)	14.67±1.46^{b}	1.58	14.52±1.51^{b}	1.51	13.21±1.58^{a}	1.46
Body length (cm)	73.95±6.35^{c}	9.12	68.11±6.54^{b}	9.60	61.91±4.85^{a}	7.83
Chest width (cm)	17.05±2.46^{b}	14.43	16.71±2.52^{b}	15.08	14.62±1.73^{a}	11.83
Chest depth (cm)	30.45±3.89	12.77	29.58±2.82	9.53	29.12±2.09	7.17
Chest girth (cm)	78.04±6.18^{b}	7.89	76.44±7.25^{b}	9.48	72.67±5.05^{a}	6.94
Ear length (cm)	28.28±4.59^{c}	16.23	19.24±3.13^{b}	16.27	13.89±1.48^{a}	10.65
Ear width (cm)	11.14±1.88^{c}	16.87	8.84±1.30^{b}	14.71	6.70±0.70^{a}	10.45

Note: SD, CV: coefficient of variation. ^{a,b,c}The average body weight and body measurements in the same row and different letters are different at $p<0.05$

Table 3. Average body indices of Etawah Crossbreed, Local Gorontalo, and Kacang goats reared by traditional semi-intensive breeders in Gorontalo Indonesia

Body Indices	Breed goat			Sig.
	Etawah Crossbreed	Local Gorontalo	Kacang goats	
Length Index (LI)	1.02±0.08	1.04 ±0.01	1.06±0.10	0.390
Depth Index (DI)	^{a}0.42±0.05	^{b}0.45±0.03	^{c}0.49±0.04	0.000
Body Index (BI)	^{b}95.02±8.00	^{ab}88.21±10.1	^{a}85.32±7.70	0.000
Conformation Index (CI)	^{a}84.42±12.00	^{ab}90.80±12.24	^{b}90.38±12.10	0.024
Proportionality (Pr)	98.52±7.28	95.40±7.30	95.55±10.8	0.155
Index of relative thoracic depth (IRDT)	^{a}42.05±5.40	^{b}45.87±3.37	^{c}49.70±3.63	0.000
Thoracic Development (TD)	^{a}1.08±0.08	^{b}1.19±0.09	^{b}1.21±0.21	0.000
Area Index (AI)	^{c}5379.5±705.8	^{b}4444±842.5	^{a}3637.3±533.4	0.000
Foreleg Length Index (FLI)	^{c}42.09±5.20	^{b}35.14±4.98	^{a}29.60±4.13	0.000
Height Slope Index (HSI)	^{b}4.17±2.36	^{a}1.60±3.42	^{a}0.96±3.26	0.000
Body Ratio (BR)	^{a}0.95±0.03	^{b}0.98±0.05	^{b}0.98±0.05	0.001

Note: ^{a,b,c}The average body weight and body measurements on the same row and different letters are different at $p<0.05$

The average length index of Local Gorontalo goats was 1.04±0.01, which was lower than Kacang goats at 1.06±0.10 and higher than Etawah Crossbreed at 1.02±0.08. Based on these results, local goats are classified as long-type goats. Generally, positive length indices <1 and >1 indicated tall breeds and long breeds, respectively. The research of Khargharia et al. (2015) on the Assam Hill goats obtained an index value of 1.14±0.02, while Putra and Ilham (2019) reported a value of 1.07±0.09 for Kacang goats. The average depth index of Local Gorontalo goats was 0.45±0.03, lower than Kacang goats of 0.49±0.04 but higher than the 0.42±0.05 of Etawah Crossbreed, thereby classified as long-legged. A depth index of >0.5 was categorized as short-legged goats, and <0.5 was long-legged goats. The research on the depth index of the Assam Hill goats obtained 0.51±0.01, hence, the goats were classified as short-legged (Khargharia et al. 2015). The average body index of Local Gorontalo goats was 88.21±10.1, lower than Etawah Crossbreed of 95.02±8.00 but higher when compared to Kacang goats of 85.32±7.70. Based on the body index, Local Gorontalo and Kacang goats were classified as medigline type, while Etawah Crossbreed goats were longiline. Furthermore, goats with a body index of >0.90 were longiline, while those with values of 0.86-0.89 and <0.85 were medigline and brevigline, respectively (Chacón et al. 2011). The body index of the Arba Minch-Zuria (AMZ) goats was 87.5 (Dea et al. 2019) and the Cuban Creole goats were 85.29±4.75 (Chacón et al. 2011). The average thoracic development score for Local Gorontalo goats was 1.19±0.09, lower than Kacang goats 1.21±0.21 but higher than the Etawah Crossbreed 1.08±0.08. Thoracic development above 1.2 was classified as a good TD category (Putra and Ilham 2019). Cuban creole goats had thoracic development of 1.26 (Chacón et al. 2011). Meanwhile, the development in Assam hill goats and AMZ goats was 1.32±0.02 (Khargharia et al. 2015) and 1.17 (Dea et al. 2019). The average foreleg length index of Local Gorontalo goats was 35.14±4.98, lower than Etawah Crossbreed goats at 42.09±5.20 and higher than Kacang goats at 29.60±4.13. The foreleg length index of the local was higher than that of Kacang goats but lower compared to the Etawah Crossbreed goats. This was due to the combination of traits during crossbreeding between the tall Etawah Crossbreed goats and the short Kacang goats. The average body ratio of Local Gorontalo goats was similar to Kacang goats, which was 0.98±0.05 and higher than the Etawah Crossbreed, with values of 0.95±0.03. A body ratio value <1 indicates the waist is higher than the shoulders, while a higher body ratio indicates the shoulders are more than the waist (Chacón et al. 2011).

Body indices that had the highest correlation with body weight were the CI for Etawah Crossbreed (0.79) and Kacang goats (0.83), while the AI (0.86) for Local Gorontalo goats, as presented in Table 4. Other body indices that strongly correlated to body weight were LI, Pr, TD, and AI in Etawah Crossbreed goats, CI and FLI on Local Gorontalo as well as, BI and AI on Kacang goats. A moderate correlation with body weight was only found in Kacang goats, namely the TD (0.38). A significant and positive correlation indicated that a high or low body index affected body weight, while a low correlation suggested an independent relationship between variables (Arandas et al. 2017). A significantly strong and positive correlation between body weight and conformation index (0.88) and Thoracic Development (0.42) was also found in Cuban Creole goats (Chacón et al. 2011). Furthermore, the strong/moderate correlation between body weight, measurements, and indices is a potential selection criterion for adult female local goats in Indonesia. This was because phenotypic and genetic correlation will support the improvement of livestock characteristics (Khandaker et al. 2017). This indicated that the use of index values for goat selection supported the increase in trait groups and economic weight in goat production systems (Lopes et al. 2012).

Principal Component Analysis of body measurements

Table 5 showed a strong positive correlation between body measurement and body weight of the three local Indonesian goats, except for the ear length of Etawah Crossbreed and Kacang goats as well as the ear width of Etawah Crossbreed. The highest correlation with body weight was chest girth in Etawah Crossbreed (0.92) and Kacang goats (0.97), as well as chest depth in Local Gorontalo (0.82), indicating a significant increase in body weight. Information on correlation among several traits is important for selection based on heritability and breeding value (Khandaker et al. 2017; Figueiredo-Filho et al. 2021). Correlation coefficients from the highest to body weight in South African non-descript indigenous goats included a withers height of 0.70, rump height of 0.40, and body length of 0.54 (Tyasi et al. 2020). In Batur sheep, the chest girth was 0.866, body length was 0.433, and withers height was 0.369 (Ibrahim et al. 2021), while Kacang goats had a chest girth of 0.83, face height of 0.59, and body length of 0.56 (Putra and Ilham 2019). Furthermore, the body measurements in Saburai goats included body length, chest girth, and shoulder height with values of 0.858, 0.956, and 0.862 (Dakhlan et al. 2021). Leg perimeter and chest circumference are also correlated with body weight and carcass. Therefore, they can be considered a selection index in the preparation of a meat-producing goat breeding program (Figueiredo-Filho et al. 2021). Several body measurement variables in the three local Indonesian goats significantly correlated with other body measurements, as presented in Table 5. This showed that the reduction to simpler and independent components is urgently needed for PCA analysis. Dimentionality reduction able to eliminate multicollinearity which is the main requirement in parametric analysis to produce simple regression equation.

Table 6 showed the value of the Kaiser-Meyer-Olkin Measure test (>0.5) and Bartlett's Test of Sphericity (0.00<0.05) from the initial analysis of three Indonesian local goat breeds. It was discovered that the amount of data was sufficient and there was no correlation between each variable in the population. Therefore, proceeding to the data reduction through PCA factor analysis was feasible. Factor analysis using the PCA method on body measurements of Local Gorontalo goats obtained two

components with eigen values of the first and second components >1, namely 4.88 and 1.297, respectively. The percentage variance of the two main components was 61.04% and 16.2%, respectively, and the accumulated variance was 77.26% against the whole variance original variable. Based on the rotated component matrix with the varimax method, the loading factor of the first component covered withers chest girth of 0.927, followed by chest depth, chest width, body length, wither height, and hip height with values of 0.911, 0.828, 0.784, 0.750, and 0.719, respectively. Meanwhile, the second component encompassed an ear length of 0.856, and an ear width of 0.784. In addition to Local Gorontalo goats, the main components formed were two Etawah Crossbreed goats with a total variation of 66.66% and three Kacang goats with 73.02%. The highest contribution to the total diversity of the first component in Etawah Crossbreed goats of mixed lines was body length at 0.83 and 0.80 in Kacang goats was wither height. The highest contribution in the second component came from the ear length of the Etawah Crossbreed goats at 0.90 and the chest width of Kacang goats at 0.88, while the third component of Kacang goats came from the ear length, which was 0.88, as illustrated in Figure 3.

The group of variables in the first component can be regarded as size markers, and those in the second component are shape markers in goats and sheep (Yakubu et al. 2011; Kurnianto et al. 2013). In Kacang goats, the first, second, and third components can be referred to as the main, supporting, and additional factors that influence the total diversity of each principal component. The first component of the Red Sokoto goats was growth characteristics, followed by birth characteristics, as well as weaning season in the second and third components, respectively (Iyiola-Tunji et al. 2016). The PCA performed on West African Dwarf (WAD) goats also found that the variable with the highest correlation to the diversity of the first component was body length with a value of 0.893, followed by Fore-leg Length at 0.824, and Neck Circumference at 0.437 in second and third components, respectively (Dudusola et al. 2019).

Table 4. Matrix correlation of body weight-body indices of Etawah Crossbreed, Local Gorontalo, and Kacang goats breeds of Indonesia

Variable	BW	LI	DI	BI	CI	Pr	IRDT	TD	AI	FLI	HSI
Etawah Crossbreed											
LI	0.43**										
DI	0.29	0.58**									
BI	-0.08	0.54**	0.18								
CI	0.79**	0.34*	0.35*	-0.52**							
Pr	-0.44**	-0.99**	-.56**	-0.55**	-0.34*						
IRDT	0.29	0.58**	0.99**	0.18	0.35*	-0.56**					
TD	0.51**	0.41*	0.40*	-0.54**	0.91**	-0.39*	0.40*				
AI	0.76**	0.34*	0.097	0.41*	0.25	0.99**	-0.36*	-0.11			
FLI	0.09	-0.53**	-0.85**	-0.07	-0.22	0.51**	-0.85**	-0.48**	0.37*		
HSI	-0.16	0.30	0.19	0.08	0.02	-0.27	0.17	0.21	-0.28	-0.37*	
BR	0.21	-0.28	-0.20	-0.05	0.00	0.25	-0.19	-0.22	0.35*	0.42**	-0.10**
Local Gorontalo											
LI	-0.13										
DI	0.01	0.48**									
BI	-0.12	0.82**	-0.04								
CI	0.55**	0.28**	0.63**	-0.15							
Pr	0.00	-0.99**	-0.68**	-0.49**	-0.38**						
IRDT	0.004	0.47**	0.99**	-0.04	0.62**	-0.68**					
TD	-0.02	0.41**	0.89**	-0.19	0.73**	-0.67**	0.89**				
AI	0.86**	-0.11	-0.23*	0.16	0.42**	0.09	-0.23*	-0.25*			
FLI	0.53**	-0.34**	-0.75**	0.09	-0.09	0.62**	-0.75**	-0.73**	0.77**		
HSI	-0.02	0.22*	0.12	0.12	0.15	-0.26*	0.13	0.20	-0.01	-0.13	
BR	0.02	-0.23*	-0.14	-0.13	-0.15	0.27*	-0.14	-0.20	0.02	0.14	-0.99**
Kacang goats											
LI	-0.18										
DI	0.12	0.51**									
BI	-0.51**	0.68**	-0.04								
CI	0.83**	0.11	0.46**	-0.56**							
Pr	0.19	-0.98**	-0.47**	-0.71**	-0.07						
IRDT	0.14	0.51**	0.99**	-0.04	0.47**	-0.46**					
TD	0.38*	0.45**	0.69**	-0.34*	0.82**	-0.39*	0.69**				
AI	0.45**	-0.07	-0.39*	0.30	0.00	0.01	-0.37*	-0.47*›			
FLI	0.19	-0.65**	-0.87**	-0.08	-0.29	0.60**	-0.86**	-0.74*›	0.68**		
HSI	-0.02	0.45**	0.36*	0.04	0.32*	-0.37*	0.35*	0.55*›	-0.33*	-0.48**	
BR	0.03	-0.46**	-0.38*	-0.04	-0.32*	0.38*	-0.36*	-0.55*›	0.34*	0.49**	-0.99

Note: *correlation is significant at the 0.05 level, **correlation is significant at the 0.01 level

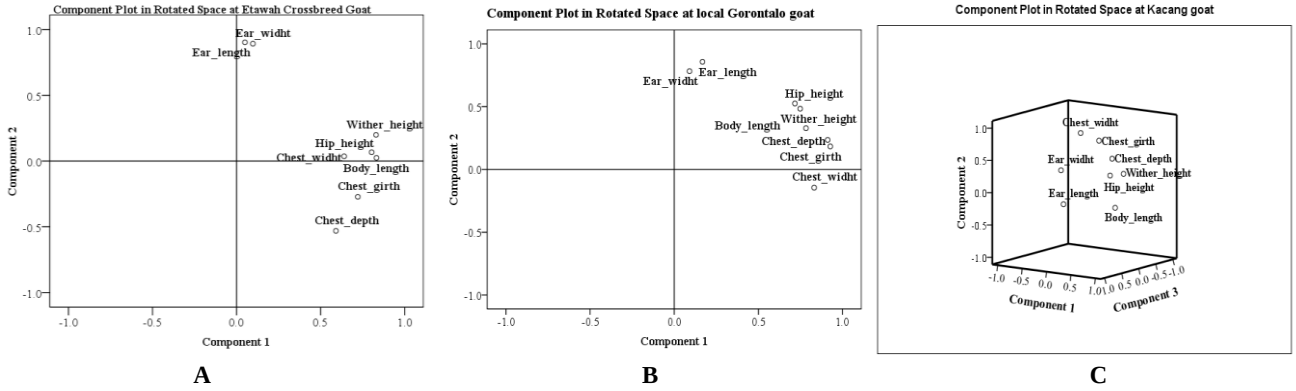
Table 5. Matrix phenotype correlation body weight and body measurement of Etawah Crossbreed, Local Gorontalo, Kacang goats

Variable	Body weight	Wither height	Hip height	Body length	Chest width	Chest depth	Chest girth	Ear length
Etawah Crossbreed								
Wither height	0.56**							
Hip height	0.53**	0.86**						
Body length	0.77**	0.56**	0.58**					
Chest width	0.53**	0.35*	0.29	0.41*				
Chest depth	0.55**	0.27	0.28	0.59**	0.38*			
Chest girth	0.92**	0.47**	0.43**	0.52**	0.50**	0.42*		
Ear length	-0.03	0.18	0.01	0.13	-0.01	-0.37*	-0.14	
Ear width	-0.06	0.15	0.03	0.11	0.24	-0.29	-1.81	0.71**
Local Gorontalo								
Wither height	0.73**							
Hip height	0.67**	0.88**						
Body length	0.81**	0.67**	0.68**					
Chest width	0.67**	0.48**	0.48**	0.49**				
Chest depth	0.82**	0.76**	0.71**	0.78**	0.65**			
Chest girth	0.80**	0.72**	0.70**	0.77**	0.70**	0.93**		
Ear length	0.37**	0.51**	0.55**	0.40**	0.08	0.33**	0.30**	
Ear width	0.26*	0.34**	0.36**	0.29**	0.08	0.32**	0.29**	0.49**
Kacang								
Wither height	0.45**							
Hip height	0.49**	0.76**						
Body length	0.27	0.25	0.29					
Chest width	0.68**	0.19	0.31	-0.01				
Chest depth	0.67**	0.57**	0.47**	0.31	0.38*			
Chest girth	0.97**	0.52**	0.56**	0.21	0.70**	0.69**		
Ear length	0.18	0.11	0.35*	0.18	0.06	0.16	0.17	
Ear width	0.45**	0.21	0.31	0.06	0.30	0.28	0.42**	0.38*

Note: **correlation is significant at the 0.01 level (2-tailed), *correlation is significant at the 0.05 level (2-tailed)

Table 6. Feasibility test of body measurements variables for PCA factor analysis and results of component matrix rotation on body measurements of Etawah Crossbreed**,** Local Gorontalo, and Kacang goats in Gorontalo Indonesia

Test	Initial Eigen Values			Rotated Component Matrix			
	Component	Total (%)	Cumulative variance (%)	Variable	Component		
					1	2	3
Etawah Crossbreed							
- Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.599	1	3.33 (41.63)	41.634	Body length	0.83		
	2	2.00 (25.03)	66.667	Wither height	0.83		
- Approx. Chi-Square: 151.098	3	0.97 (12.12)	78.788	Hip height	0.80		
- Bartlett's Test of Sphericity: 0.00	4	0.66 (8.31)	87.097	Chest girth	0.72		
	5	0.51 (6.39)	93.477	Chest width	0.64		
	6	0.23 (2.91)	96.389	Chest depth	0.59		
	7	0.19 (2.38)	98.773	Ear length		0.90	
	8	0.09 (1.22)	100.000	Ear widht		0.89	
Local Gorontalo							
- Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.849	1	4.88 (61,04%)	61.04	Chest girth	0.927		
	2	1.297 (16,2%	77.26	Chest depth	0.911		
- Approx. Chi-Square: 602.931	3	0.627 (7,83%)	85.09	Chest width	0.828		
- Bartlett's Test of Sphericity: 0.00	4	0.431 (5,39%)	90.49	Body length	0.784		
	5	0.370 (4,62%)	95.11	Wither height	0.750		
	6	0.218 (2,73%)	97.84	Hip height	0.719		
	7	0.111 (1,39%)	99.23	Ear length		0.856	
	8	0.061 (0,76%)	100.000	Ear widht		0.784	
Kacang goats							
- Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.692	1	3.50 (43.78%)	43.779	Wither height	0.80		
	2	1.20 (15.03%)	58.810	Hip height	0.72		
- Approx. Chi-Square: 123.252	3	1.14 (14.21%)	73.024	Body length	0.70		
- Bartlett's Test of Sphericity: 0.00	4	0.79 (9.82%)	82.847	Chest depth	0.60		
	5	0.56 (7.03%)	89.879	Chest width		0.88	
	6	0.47 (5.94%)	95.822	Chest girth		0.82	
	7	0.17 (2.15%)	97.973	Ear length			0.88
	8	0.16 (2.02%)	100.000	Ear widht			0.72



A **B** **C**

Figure 3. Component plot of body measurement after rotation component. A. Etawah Crossbreed goats. B. Local Gorontalo. C. Kacang goats

The naming of each principal component was subjective and no provisions must be followed for the process. Variables in components can be considered in selection of Local Gorontalo goats to ensure the effectiveness and efficiency of selection. The size markers of four Indonesian female local goats, namely Kejobong, Ettawah crossbreed, Kacang, and Jawarandu goats included chest circumference, chest depth, body length, withers height with values of 0.438, 0.193, 0.327, and 0.463, while shape characteristics are chest width 0.114, hip height -0.535, and hip width 0.198 (Kurnianto et al. 2013). Size markers in Anglo-Nubian goats were body length 0.47, chest circumference 0.47, withers height 0.44, their shape markers involve chest width 0.54, rump height -0.53, and rump width 0.51 (Ribeiro et al. 2018).

The results showed that the frequency and distribution of morphology qualitative of the three breeds of Local Gorontalo goats varied significantly, except for the horns, beard, and tail direction. The body measurements of Local Gorontalo goats tended to be similar to those of the Etawah Crossbreed compared to Kacang goats. The Etawah Crossbreed goats can be classified as having a long body length, long-legged, and longline goats. Local Gorontalo goats have a long body, long-legged, medigline, and Kacang goats can be classified as having a long body, long-legged, medigline, and good thoracic development. All three local goats' breeds have a waist that is higher than their shoulders. The conformation index significantly correlated with body weight in the three local goats' breeds, making it an important consideration in selection process. The first component variables that can be considered in selection program for Etawah Crossbreed, Local Gorontalo, and Kacang goats sequentially are body length, chest girth, and height. Meanwhile, the second component is ear length and chest width, and the third component in Kacang goats is ear length.

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