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Morphometrics Characterization of Thin-Tail Sheep in Lowland and Highland Areas

Depison[a,*], W. P. B. Putra[b], Gushairiyanto[a], Y. Alwi[a], & H. Suryani[a]
[a]Faculty of Animal Science, Jambi University
Jambi-Muara Bulian Rd. Km 15, Muaro Jambi, Jambi, Indonesia 36122
[b]Research Center for Biotechnology, Indonesian Institute of Science
Bogor-Jakarta Rd. Km 46, Cibinong, Bogor, West Java, Indonesia 16911
*Corresponding author: depison.nasution@unja.ac.id
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ABSTRACT

Breed characterization in the livestock is important for the breeding program in the future. This research aimed to characterize Thin-tail sheep in the highland and lowland areas of Jambi Province based on 7 body measurements and body indices using multivariate analysis. Data were collected from 160 sheep consisted of 80 rams and 80 ewes from each area (320 sheep in total with 1-2 years old). The research showed that the principal component analysis (PCA) in this study was explained 65.84%-72.30% by body measurements and 78.23%-84.99% by body indices of the total phenotypic variance of animals. The body measurement of cannon circumference (CC) and body indices of area index (AI), relative cannon index (RCI), dactyl thorax index (DTI), conformation index (CI), and index of body weight (IBW) were selected as the discriminating variable for Thin-tail sheep in different areas. However, this study's canonical correlation (rc) values were 0.44 for body measurements and 0.47 for body indices. Therefore, about 67.5% of Thin-tail sheep from the lowland area and 57.5% of Thin-tail sheep from the highland area can be characterized with body measurements. Hence, about 61.2% of Thin-tail sheep from the lowland area and 65.6% of Thin-tail sheep from the highland area can be characterized with body indices. Temperature, humidity, rainfall, and length of radiation in the highland areas are lower than in the lowland areas. The cluster analysis in four Thin-tail sheep populations revealed two clusters, i.e., cluster 1 consisted of Kerinci and Sungai Penuh and cluster 2 consisted of Muaro Jambi and Batanghari. It was concluded that about 60% of Thin-tail sheep could be characterized through their body indices.

Keywords: thin-tail sheep; characterization; principal component; canonical correlation; cluster

INTRODUCTION

Thin-tail sheep are local Indonesian sheep kept by smallholders for meat production. Sheep are livestock that are beneficial for human interests, namely as a food source for animal protein. The average weaning weight of Thin-tail lambs in Sedan Village was 8.53±1.57 kg (Najmuddin & Nasich, 2019). The average body weight for one year old male sheep was 27.834±6.914 kg and female 22.798±2.823 kg (Ashari *et al*., 2015). In addition, the average litter size and lambing interval in Thin-tail ewes were 1.82±0.42 lamb/ewe/year and 9.66±0.69 months, respectively (Najmuddin & Nasich, 2019). One of the breeding tracts for Thin-tail sheep in Indonesia is located in Jambi Province. The total number of sheep in this province in 2017 reached 76,370 heads or 0.46% of the total sheep population (16,462,274 heads) in Indonesia (KEMENTAN RI, 2017).

One of the breeding tracts of Thin-tail sheep in Indonesia locates in lowland and highland areas of Jambi Province. The morphometric characterization of livestock is important for planning improvement, sustainable utilization, conservation strategies, and breeding programs (FAO, 2012). In small-ruminant animals, morphometric characterization can be performed with body measurements and body indices (Esquivelzeta *et al*., 2011; Ouchene-Khelifi *et al*., 2018; Putra & Ilham, 2019; Markovic *et al*., 2019). Moreover, previous studies have classified the small-ruminant animals from different populations based on their morphometrics (Zaitoun *et al*., 2005; Traore *et al*., 2008; Nafti *et al*., 2014; Dekhili *et al*., 2014; Gatew *et al*., 2015; Hosseini *et al*., 2016; Birhanie *et al*., 2019; Jarquin *et al*., 2019).

Recently, the morphometrics characterization in livestock can be performed using three statistical analyses of principal component analysis (PCA), canonical discriminant analysis (CDA), and hierarchical cluster analysis (HCA). Moreover, these statistical analyses are widely used to characterize small-ruminant breeds from different populations (Birteeb *et al*., 2012; Aziz and Al-Hur, 2013; Boujenane *et al*., 2016; Dauda *et al*., 2018; N'Goran*et al*., 2019; Nunes *et al*., 2020).

Morphometric characterization can be carried out on body measurements, including body length, chest girth, wither height, rump height, chest depth, canon-bone length, canon-bone circumference, pelvic width, rump length, and rump width (Getahun *et al*., 2020; Josiane *et al*., 2020). Morphometrics can also be used to estimate body weight (Sabbioni *et al*., 2020), livestock selection, and preservation (Ashifudin *et al*., 2017). Morphometric data are needed for livestock identification, prediction of production potential, livestock productivity (Hilmawan *et al*., 2019; Mahmudi *et al*., 2019), continuity of breeding and livestock breeding (Saputra *et al*., 2019; Markovic *et al*., 2019). Several morphometric studies have been carried out on sheep to improve genetic quality based on morphometric data (Vazic *et al*., 2017; Salvagno & Albarella, 2017; Sanni *et al*., 2018; Markovic *et al*., 2019). Linear Body Parameters and Craniometric Analysis in Etawah-Grade goats were used to predict prolificacy (Mulyono *et al*., 2018). However, there is no information regarding the morphometric characteristics of Thin-tail sheep in two different areas, namely the lowland and the highland areas. It is thought that different land-area conditions can affect the morphometric characteristics of livestock. This study aimed to characterize the morphometric characteristics of thin-tail sheep raised in the lowland and highland areas. The results of this study will be used as a basis for planning improvement, sustainable utilization, conservation strategies, conservation strategies, and breeding programs for thin-tail sheep in the highland area and lowland area in the future.

MATERIALS AND METHODS

Research Site and Animals

This research was conducted in the lowland area (0-100 m asl) and in the highland area (>500 m asl) of Jambi Province of Indonesia locating at latitude 0°45′-2°45′ S and longitude 101°10′-104°55′ E. (Central Bureau of Statistic, Jambi Province, 2021). Hence, the research sites of the highland area consisted of Sungai Penuh City (Kumun Debai Subdistrict and Tanah Kampung Subdistrict) and Kerinci Regency (Air Hangat Subdistrict and Depati Tujuh Subdistrict). Meanwhile, the research sites of the lowland area consisted of Muaro Jambi Regency (Sekernan Subdistrict and Kumpeh Subdistrict) and Batanghari Regency (Muaro Tembesi Subdistrict and Pemayung Subdistrict). The climatic conditions in the study areas were presented in Table 1. Therefore, the research sites of this study were illustrated in Figure 1.

A total of 320 Thin-tail sheep were collected from two areas of lowland (160 sheep) and highland (160 sheep) with a sex proportion of 80 rams and 80 ewes for each area. The sheep-raising system in both locations was the same, namely, the sheep were released in the morning and in the afternoon, they were kept in captivity.

Management of Animal

The lowland sheep and highland sheep were reared by the farmers with a semi-extensive farming system. The maintenance system applied was the experimental sheep were released in the morning and in the evening without being given forage or concentrates in the cage. The mating system was also occurred naturally.

Data Collection

The body measurements were taken from animals in a standing position with a raised head. Body measurements of animals were performed using a measuring stick and flexible measuring tape and taken based on the guideline of FAO (2012). Therefore, the weighing scale was used to obtain body weight (BW) of animals.

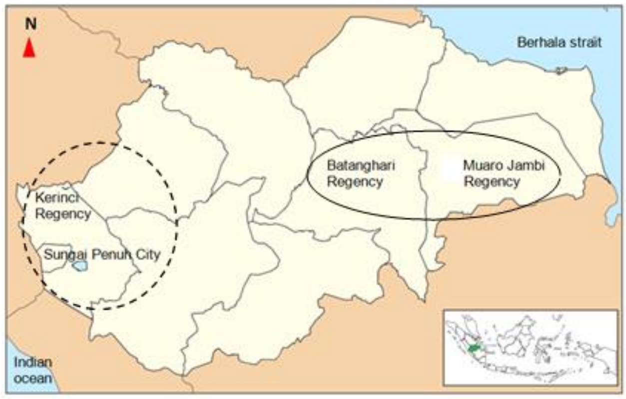

Figure 1. The Thin-tail sheep population in Jambi Province of Indonesia spread at lowland area (Batanghari Regency and Muaro Jambi Regency) and highland (Kerinci Regency and Sungai Penuh City) areas.

Table 1. Climatic condition of the study area

Description	Highland		Lowland	
	Sungai Penuh City	Kerinci Regency	Batanghari Regency	Muaro Jambi Regency
Temperature (^{o}C)	22.50	22.80	26.80	26.80
Wind speed (m/sec.)	4.30	4.00	5.42	5.42
Humidity (%)	82.00	82.00	85.00	85.00
Air pressure (mb)	923.89	923.89	1009.50	1009.50
Rainy day	190.00	190.00	207.00	207.00
Sun ilumination (%)	57.00	57.00	116.97	124.58
Rainfall (mm)	2.052,80	2.052,80	2.500.00	2.500,00
Regional high (asl)	>1000	>1000	20	25

Source: Central Bureau of Statistic, Jambi Province year 2019.

Eight body measurements consisted of body length (BL), withers height (WH), chest girth (CG), chest depth (CD), shoulder width (SW), rump height (RH), rump width (RW), and cannon circumference (CC). Body length (BL) was measured from the point of the shoulder to the pin bone. Wither height (WH) was measured from the surface of a platform on which an animal stands to the withers of the animal. Chest girth (CG) was measured as the body circumference just behind the forelegs. Chest depth (CD) was measured from the most dorsal point of the withers to the ventral surface of the sternum. Shoulder width (SW) was measured as a distance from the left to the right shoulder blade. Rump height (RH) was measured from the surface of a platform to the rump. Rump width (RW) was measured as a distance between two *tuber coxae.* The scheme of body measurements in Thin-tail sheep was presented in Figure 2. Moreover, calculation of body indices were obtained in this study according to Birteeb *et al.* (2014), Khargharia *et al.* (2015), and Boujenane *et al.* (2015) as follow: Length index (LI)= [BL/WH]×100, Thoracic index (TI)= [SW/CD]×100, Depth index (DI)= [CD/WH]×100, Height index (HI)= [WH/RH]×100, Thoracic development (TD)= [CG/WH]×100, Dactyl thorax index (DTI)= [CC/CG]×100, Conformation index (CI)= CG^2/WH, Relative cannon index (RCI)= [CC/WH]×100, Index of body weight (IBW)= [BW/WH]×100, Body index (BI)= [BL/CG]×100, Proportionality (Pr)= [WH/BL]×100, Area index (AI)= WH×BL.

According to DTI value, the body of sheep can be described into four categories, i.e., light animals (DTI<10.5), intermediary animals (10.6<DTI<10.8), light meat-type animals (10.9<DTI<11.0), and heavy meat-type animals (DTI>11.0). According to the BI value, the body of sheep can be described into three categories, i.e., short or brevigline animals (BI<85), medigline animals (86<BI<88), and longline animals (BI>88) types (Esquivelzeta *et al.,* 2011; Chacon *et al.,* 2011).

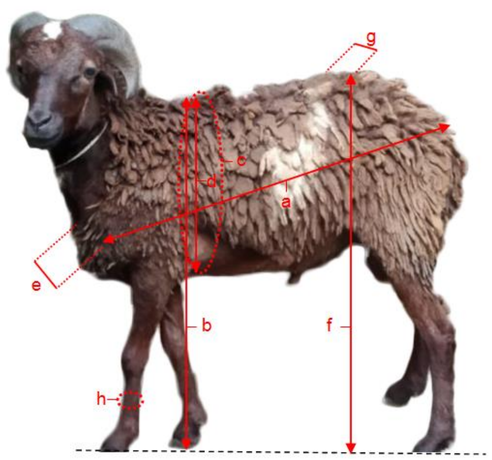

Figure 2. Body measurements scheme in Thin-tail sheep.
a. body length (BL), b. withers height (WH), c. chest girth (CG), d. chest depth (CD), e. shoulder width (SW), f. rump height (RH), g. rump width (RH), h. cannon circumference (CC).

Statistical Analysis

The statistics parameter of mean, standard deviation, and Pearson's correlation coefficient (r) for body measurements and body indices were calculated with the SPSS 16.0 computer program. Meanwhile, the morphometric characterization in sheep was performed using three statistical analyses of principal component anaysis (PCA), canonical discriminant analysis (CDA), and hierarchical cluster analysis (HCA) using a similar computer program. The PCA was used to define the underlying structure among the variables in the analysis (Yunusa *et al.*, 2013). The CDA was used to classify an observation, or several observations, into already known groups (Asamoah-Boaheng & Sam, 2016). The HCA aimed to separate cases / objects into several groups that have different characteristics (Oliveira *et al.*, 2018). In the PCA, Kaiser-Meyer-Olkin (KMO) measures of sampling adequacy and Bartlett's test of sphericity and communality were computed as the test validity. The KMO statistics vary between 0 and 1. The value close to 0 indicates that there are large partial correlations compared to the total of correlations. A value close to 1 indicates that the sampling is appropriate. It was possible to accept a measure of sampling adequacy greater than 0.50. The varimax criterion of the orthogonal rotation method was employed in the rotation of the factor matrix to enhance the interpretability of the factor analysis. In CDA, Mahalanobis distance (D^2), tolerance (T), Wilk's lambda (λ) values and linear discriminant function were computed to obtain the discriminating variable for thin-tail sheep at two different areas. Here CDA was applied with the backward stepping automatic elimination method, with F value entry = 3.84 and F value removal= 2.71. The T value (0 to 1) was computed to detect the level of correlation among variables in the discriminant function. If a variable is highly correlated with one or more of the others, the T value is very small and the resulting estimates of the discriminant function coefficients may be unstable. The HCA was used to cluster Thin-tail sheep from different populations. The HCA in this study was performed using combination data (body weight, body measurements, and body indices) with the nearest neighbor method, Euclidean distance measure, and transform the value of Z score, counted by the following formula:

$$Z = (x - \mu) / \sigma$$

where x was the observed value (raw score), μ was population mean, σ was the standard deviation of the population, and Z was Z Score (Standard Value).

RESULTS

Animal Morphometrics

Table 1 shows that the temperature, humidity, rainfall, and duration of radiation in the highland areas are lower than in the lowland areas. The morphometrics of Thin-tail sheep is presented in Table 2. The averages of

BW, BL, WH, CG, SW, RH, and RW of Thin-tail population at highland areas were higher than those in lowland areas (p<0.05). Meanwhile, the body indices of Thin-tail population at lowland areas and highland areas were not significantly different. However, the eight body indices of LI, TI, DI, TD, CI, RCI, IBW, and Pr in sheep in highland areas were higher than those in sheep in lowland areas. Commonly, the body weight, body measurements, and body indices in rams were higher than in ewes in each area. Nevertheless, the body indices of HI between rams and ewes in highland areas were similar.

Thin-tail sheep in the highlands   Thin-tail sheep in the lowlands

Figure 3. Thin-tail sheep in the highlands and lowlands in Jambi Province (The sheep in the highlands have various colors, in the lowlands generally light brown).

Phenotypic Correlation

The correlation values among BW and body measurements ranged from 0.16 (BW-CG) to 0.65 (BW-WH) for thin-tail sheep at lowland areas and 0.34 (BW-RW) to 0.65 (BW-CG) for thin-tail sheep at highland areas (Table 3). Therefore, the r-value among BW and body indices (without IBW) ranged from -0.38 (BW-TI) to 0.08 (BW-CI) for thin-tail sheep at lowland areas and -0.03 (BW-LI) to 0.64 (BW-AI) for thin-tail sheep at highland areas (Table 4).

The grasses consumed by thin-tail sheep at the lowland areas are generally *A. Compresssus*, *O. Nodosa*, *L. Hexandra*, and *C. Dactylon* with averages chemical compositions, namely Crude Protein 9.33%, Crude Fiber 30.70%, Crude fat 1.44%, and Ash 10.55% (Table 5). In the highland areas, thin-tail sheep generally consumed the grasses of *L. hexandra*, *B. muticum*, *D. ciliaris*, *O. nodosa*, and *E. colona*, with averages chemical compositions of Crude Fiber 10.12%, Crude Fiber 29.61%, Crude fat 1.63%, and Ash 10.30% (Table 5).

Table 2. The average of morphometric traits in Thin-tail sheep at two different areas

Variables	Lowland			Highland		
	Ram (N=80)	Ewe (N=80)	Total (N=160)	Ram (N=80)	Ewe (N=80)	Total (N=160)
Body weight (kg)	16.46±3.27	15.25±2.33	15.86±2.89[a]	18.85±2.44	16.23±3.21	17.54±3.13[b]
Body measurements (cm)						
Body length	50.43±5.01	48.37±4.52	49.40±4.87[a]	53.26±4.40	49.94±5.31	51.60±5.14[b]
Wither height	51.63±4.20	49.15±2.71	50.39±3.74[a]	53.76±4.13	50.57±4.49	52.16±4.59[b]
Chest girth	54.61±14.80	51.28±3.71	52.4±10.89[a]	56.73±3.34	53.64±4.51	55.18±4.25[b]
Chest depth	23.74±2.35	21.60±4.09	22.67±3.49	24.13±1.97	23.27±4.27	23.70±3.34
Shoulder width	11.54±1.10	10.51±1.09	11.02±1.21[a]	13.00±0.80	10.68±1.25	11.84±1.56[b]
Rump height	53.33±4.79	51.26±3.72	52.30±4.40[a]	56.00±3.70	52.79±5.34	54.40±4.85[b]
Rump width	12.71±2.05	11.81±1.21	12.26±1.74[a]	14.19±2.78	12.57±1.47	13.38±2.36[b]
Cannon circumferance	6.89±0.61	5.98±0.51	6.44±0.72	7.80±0.54	6.53±0.32	7.17±0.78
Body indices						
Length index	97.72±6.06	98.40±6.55	98.06±6.30	99.26±6.73	98.94±7.77	99.10±7.25
Thoracic index	48.99±5.95	49.42±6.53	49.20±6.23	54.05±3.21	46.63±6.57	50.34±6.35
Depth index	46.07±4.03	43.89±6.95	44.98±5.77	45.11±4.63	46.05±7.16	45.58±6.03
Height index	97.13±7.26	96.27±7.79	96.70±7.52	96.02±4.27	96.19±7.59	96.10±6.14
Thoracic development	106.24±29.30	104.36±5.60	105.30±21.05	105.92±7.37	106.40±8.32	106.16±7.84
Dactyl thorax index	26.55±13.62	23.12±2.79	24.84±9.95	24.99±4.56	23.57±3.21	24.28±3.99
Conformation index	62.03±28.64	53.65±5.65	57.84±21.00	60.15±6.15	57.23±7.48	58.69±6.98
Relative cannon index	24.67±3.99	24.03±2.14	24.35±3.21	26.51±5.34	24.99±3.16	25.75±4.44
Index of body weight	31.78±5.15	30.95±3.83	31.36±4.54	35.12±4.21	31.95±4.88	33.54±4.82
Body index	102.72±42.32	94.65±9.49	98.68±30.84	94.00±7.32	93.48±10.08	93.74±8.78
Proportionality	2620.02±442.89	2384.71±338.33	2502.37±410.19	2874.97±413.47	2540.73±462.93	2707.85±468.53
Area index	102.72±6.37	101.99±5.73	102.36±6.05	101.20±6.83	101.61±7.05	101.41±6.92

N: number of animals. Means in the same row with different superscripts differ significantly (p<0.05)

Table 3. Person's correlations between body weight and body measurements of Thin-tail sheep at lowland (above diagonal) and highland (under diagonal) areas

Body measurements	BW	BL	WH	CG	CD	SW	RH	RW	CC
Body weight (BW)	-	0.61**	0.65**	0.16*	0.55**	0.23**	0.64**	0.48**	0.42**
Body length (BL)	0.55**	-	0.73**	0.09	0.43**	0.18**	0.47**	0.43**	0.32**
Wither height (WH)	0.64**	0.69**	-	0.24**	0.51**	0.28**	0.66**	0.43**	0.40**
Chest girth (CG)	0.65**	0.51**	0.62**	-	0.18**	0.06	0.27**	-0.26**	0.24**
Chest depth (CD)	0.49**	0.36**	0.35**	0.40**	-	0.22**	0.46**	0.43**	0.39**
Shoulder width (SW)	0.54**	0.39**	0.40**	0.40**	0.25**	-	0.23**	0.47**	0.38**
Rump height (RH)	0.57**	0.55**	0.81**	0.53**	0.31**	0.39**	-	0.39**	0.49**
Rump width (RW)	0.34**	0.37**	0.23**	0.36**	0.32**	0.55**	0.23**	-	0.39**
Cannon circumferance (CC)	0.53**	0.43**	0.45**	0.43**	0.25**	0.73**	0.41**	0.44**	-

Note: *(p<0.05); **(p<0.01)

Table 4. Person's correlations between body weight and body indices of Thin-tail sheep at lowland (above diagonal) and highland (under diagonal) areas

Body indices	BW	LI	TI	DI	HI	TD	DTI	CI	RCI	IBW	BI	Pr	AI
Body weight (BW)	-	0.16*	-0.38*	0.27**	-0.09	-0.10	0.14	0.08	0.04	0.92**	0.18*	0.17*	-0.67**
Length index (LI)	-0.03	-	-0.13	0.12	-0.01	-0.09	0.14	-0.08	0.09	0.23**	0.31**	-0.98**	0.39**
Thoracic index (TI)	0.09	-0.03	-	-0.52**	0.11	-0.02	-0.03	-0.10	0.03	-0.31**	-0.06	0.16*	-0.35**
Depth index (DI)	0.10	0.25**	-0.47**	-	-0.19*	0.08	0.12	0.13	0.27**	0.33**	0.05	-0.14	0.06
Height index (HI)	0.05	-0.06	-0.01	-0.12	-	-0.16*	0.01	-0.12	-0.32**	-0.23**	0.13	0.04	0.22**
Thoracic development (TD)	-0.07	0.28**	-0.05	0.38**	-0.17*	-	-0.82**	0.96**	-0.25**	-0.06	-0.91**	0.13	-0.18*
Dactyl thorax index (DTI)	0.06	0.09	0.38**	-0.02	-0.05	-0.37**	-	-0.78**	0.28**	0.15*	0.93**	-0.18*	0.12
Conformation index (CI)	0.37**	0.15	-0.001	0.25**	-0.06	0.81**	-0.43**	-	-0.36**	0.05	-0.82**	0.14	0.04
Relative cannon index (RCI)	0.03	0.29**	0.36**	0.24**	-0.16*	0.36**	0.72**	0.18*	-	0.10	-0;02	-0.12	-0.02
Index of body weight (IBW)	0.87**	0.14	0.07	0.30**	-0.07	0.27**	0.08	0.46**	0.25**	-	0.15	-0.25**	0.37**
Body index (BI)	0.04	0.58**	0.01	-0.11	0.08	-0.61**	0.40**	-0.58**	-0.08	-0.10	-	-0.33**	0.27**
Proportionality (Pr)	0.04	-0.99**	0.03	-0.27**	0.08	-0.30**	-0.10	-0.15	-0.31**	-0.15	-0.55**	-	-0.34**
Area index (AI)	0.64**	0.17*	0.05	-0.19*	0.21**	-0.44**	0.03	0.10	-0.27**	0.25**	0.49**	-0.12	-

Note: *(p<0.05); **(p<0.01)

Table 5. Nutritional content of forage in highland areas (Kerinci Regency and Sungai Penuh City) and lowland areas (Batanghari Regency and Muaro Jambi Regency)

Location	Grass species	Crude proten (%)	Crude fiber (%)	Ether extract (%)	Ash (%)
High land	*Leersia hexandra*	9.84	27.97	1.33	8.30
	Brachiaria muticum	10.48	28.00	1.52	10.77
	Digitaria ciliaris	10.66	31.22	2.03	11.70
	Ottochloa nodosa	9.74	31.26	1.37	10.25
	Echinochloa colona	9.89	29.59	1.90	10.47
	Means	10.12	29.61	1.63	10.30
Low land	*Axonopus compresssus*	9.45	33.05	1.67	11.20
	Brachiaria muticum	8.92	30.97	1.43	9.95
	Ottochloa nodosa	8.38	30.04	1.40	10.23
	Leersia hexandra	9.19	33.08	1.43	11.09
	Cynodon dactylon	9.91	26.38	1.29	10.28
	Means	9.33	30.70	1.44	10.55

Principal Component Analysis

The PCA of body measurements in Thin-tail sheep revealed that Thin-tail sheep at lowland areas had 3 PC's and Thin-tail sheep at highland areas had 2 PC's (Table 6). The PCA of body measurements was accounted 72.30% in Thin-tail sheep at lowland areas and 65.84% in Thin-tail sheep at highland areas of total variance in animal morphometrics. Therefore, the PCA of body indices in Thin-tail sheep at lowland areas had 4 PC's and Thin-tail sheep at highland areas with 5 PCs (Table 7). The PCA of body indices were accounted 78.23% in Thin-tail sheep at lowland areas and 84.99% in Thin-tail sheep at highland areas of the total variance

Table 6. Eigenvalues, total variance, cumulative, communalities, Kaiser-Meiyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity in the body measurements of Thin-tail sheep at two different areas

Body measurements	Lowland				Highland		
	PC1	PC2	PC3	EC	PC1	PC2	EC
Body weight	0.83*	0.18	0.02	0.73	0.73*	0.41	0.70
Body length	0.84*	0.03	-0.10	0.71	0.73*	0.27	0.61
Wither height	0.86*	0.17	0.10	0.78	0.91*	0.13	0.85
Chest girth	0.16	0.07	0.92*	0.88	0.72*	0.30	0.61
Chest depth	0.66*	0.26	0.06	0.50	0.49*	0.26	0.30
Shoulder width	0.07	0.88*	-0.06	0.79	0.27	0.85*	0.80
Rump height	0.74*	0.25	0.24	0.66	0.84*	0.12	0.73
Rump width	0.37	0.56*	-0.52	0.82	0.12	0.79*	0.70
Cannon circumferance	0.49	0.66*	0.27	0.65	0.34	0.76*	0.64
Eigenvalues	4.18	1.31	1.02	-	4.72	1.21	-
Variance (%)	46.39	14.53	11.38	-	52.42	13.42	-
Cumulative (%)	46.39	60.92	72.30	-	52.42	65.84	-
KMO	0.81				0.84		
Barlett's test	**				**		

Note: *main component; PC: principal component; EC: extraction communality; **(p<0.01).

Table 7. Eigenvalues, total variance, cumulative, communalities, Kaiser-Meiyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity in the body indices of Thin-tail sheep at two different areas

Body indices	Lowland					Highland					
	PC1	PC2	PC3	PC4	EC	PC1	PC2	PC3	PC4	PC5	EC
Length index	0.08	0.98*	0.09	-0.02	0.97	0.11	0.98*	0.13	-0.02	-0.07	0.99
Thoracic index	0.06	-0.01	-0.83*	0.19	0.73	0.08	-0.01	0.27	0.003	0.88*	0.85
Depth index	0.01	0.00	0.75*	0.33	0.67	0.28	0.14	0.26	-0.13	-0.81*	0.84
Height index	0.14	-0.04	-0.19	-0.74*	0.61	-0.05	-0.11	-0.08	0.45	0.004	0.22
Thoracic development	-0.97*	-0.01	0.02	0.15	0.96	0.81*	0.17	0.01	-0.53*	-0.10	0.97
Dactyl thorax index	0.96*	0.08	0.12	0.11	0.95	-0.14	0.12	0.97*	0.04	0.04	0.98
Conformation index	-0.92*	-0.01	0.17	0.04	0.87	0.95*	0.05	-0.01	-0.02	-0.01	0.91
Relative cannon index	0.57*	0.15	0.13	0.56	0.68	0.24	0.18	0.92*	-0.19	0.01	0.97
Index of body weight	0.09	0.24	0.65*	0.17	0.52	0.65*	0.06	0.19	0.42	-0.13	0.66
Body index	0.93*	0.22	0.10	-0.11	0.94	-0.60	0.66*	0.11	0.42	0.02	0.98
Proportionality	-0.12	-0.97*	-0.11	-0.03	0.96	-0.12	-0.97*	-0.15	0.06	0.08	0.98
Area index	0.11	0.39	0.47	-0.57*	0.72	0.02	0.22	-0.02	0.89*	0.12	0.85
Eigenvalues	4.20	2.50	1.60	1.26	-	3.18	2.76	1.68	1.44	1.13	-
Variance (%)	34.96	20.79	13.36	9.12	-	26.54	22.99	13.98	12.03	9.45	-
Cumulative (%)	34.96	55.75	69.11	78.23	-	26.54	49.53	63.61	75.54	84.99	-
KMO	0.53					0.41					
Barlett's test	**					**					

Note: *main component; PC: principal component; EC: extraction communality; **(p<0.01).

in animal morphometrics. The component plot of Thin-tail sheep's body measurements and body indices were illustrated in Figure 4 and Figure 5.

Canonical Discriminant Analysis

The CDA revealed that one body measurement (CC) and five body indices (AI, RCI, DTI, CI, and IBW) were identified as the describing variables for Thin-tail sheep at lowland areas and highland areas (Table 8). The morphometric characterization in this study revealed moderate canonical correlation values for body measurements (0.44) and body indices (0.47). Moreover, about 67.50% of Thin-tail sheep at lowland areas and 57.50% of Thin-tail sheep at highland areas can be characterized based on body measurements (Table 9). Meanwhile, about 61.20% of Thin-tail sheep at lowland areas and 65.60% of Thin-tail sheep at highland areas can be characterized with body indices. The canonical plot of body measurements and body indices of Thin-tail sheep were illustrated in Figure 6.

Hierarchical Cluster Analysis

The HCA based on body weight, body measurements, and body indices were revealed two clusters

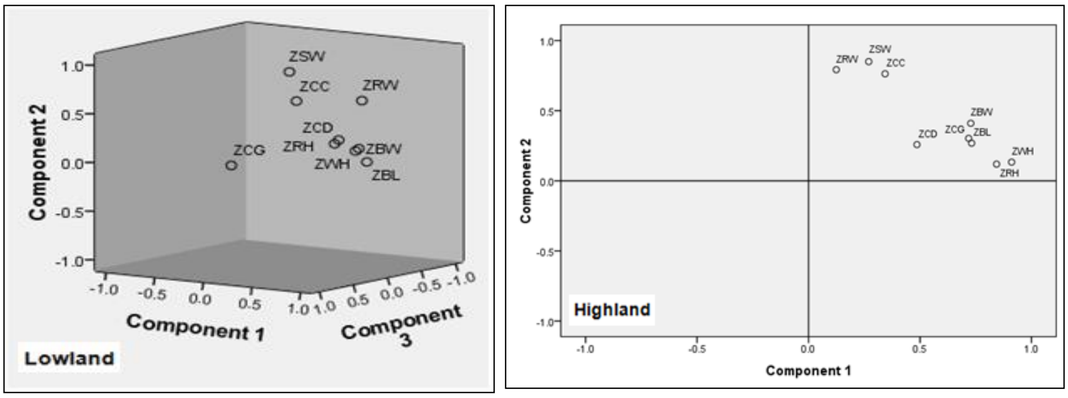

Figure 4. Component plot in rotated space for body measurements (included body weight) inThin-tail sheep

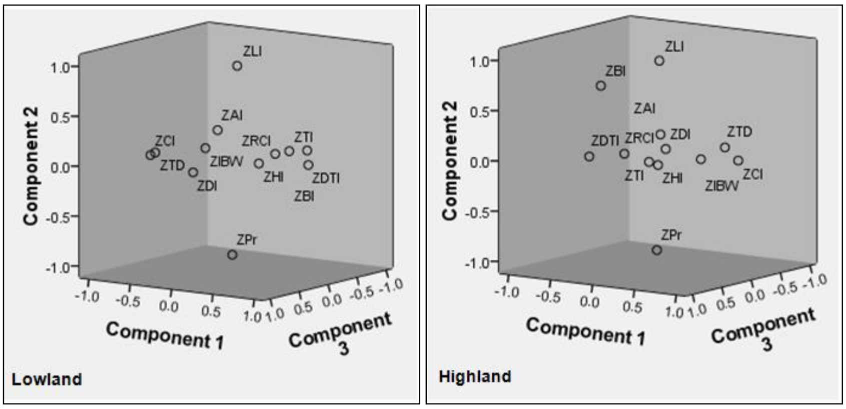

Figure 5. Component plot in rotated space for body indices in Thin-tail sheep

Table 8. Factor selected by stepwise discriminant analysis to characterize Thin-tail sheep at two different areas

Factor / Step	Variables entered	Tolerance	F_{remove}	D²	Wilk's λ
Body measurements (rc = 0.44)					
Step 1	Cannon circumferance	1.00	76.40	0.96	0.81
Body indices (rc = 0.47)					
Step 1	Area index	0.78	28.70	0.68	0.86
Step 2	Relative cannon index	0.36	50.59	0.40	0.91
Step 3	Dactyl thorax index	0.18	46.95	0.44	0.90
Step 4	Conformation index	0.30	28.63	0.68	0.86
Step 5	Index of body weight	0.82	6.73	0.99	0.80

Note: D²: Mahalanobis distance; rc: canonical correlation.

of Thin-tail sheep at highland areas (Kerinci/KR and Sungai Penuh/SP) and Thin-tail sheep at lowland areas (Muaro Jambi/MJ and Batanghari/BA) (Figure 7). The lowest Euclidean distance showed in Kerinci-Sungai Penuh (12.70) and the highest showed in Kerinci-Batanghari (71.04) (Table 10). Moreover, the Euclidean distance in Muaro Jambi-Batanghari (30.33) was closed to Muaro Jambi-Sungai Penuh (32.05).

DISCUSSION

Animal Morphometrics

Table 1 shows that the temperature, humidity, rainfall, and duration of radiation in the highland areas are lower than in the lowland areas. These differences will cause differences in livestock productivity. The difference in livestock productivity is closely related to temperature and humidity factors (Rashamol *et al*., 2018). The interaction of temperature and humidity or "Temperature Humidity Index" (THI) can affect the comfort of life for livestock and in turn will affect the condition and productivity of livestock. High rainfall, temperature, and humidity are associated with livestock disease problems and internal and external parasites. In addition to these disease problems, many of the soil minerals are leached out during the rainy season. Nutrients are removed from the soil solution, taken by plant roots, or immobilized by microorganisms also affect the rate of percolation and leaching (de Andrade *et*

Table 9. Percentage (%) of individual classification per breed based on discriminant analysis

Factor	Variables	Area	Predicted group membership (N)		Total (N)
			Lowland	Highland	
Body measurements	Original	Lowland	70.0 (112)	30.0 (48)	100.0 (160)
		Highland	45.5 (68)	57.5 (92)	100.0 (160)
	Cross-validated	Lowland	67.5 (108)	32.5 (52)	100.0 (160)
		Highland	42.5 (68)	57.5 (92)	100.0 (160)
Body indices	Original	Lowland	62.5 (100)	37.5 (60)	100.0 (160)
		Highland	33.1 (53)	66.9 (107)	100.0 (160)
	Cross-validated	Lowland	61.2 (98)	38.8 (62)	100.0 (160)
		Highland	34.4 (55)	65.6 (105)	100.0 (160)

Note: N= number of animals.

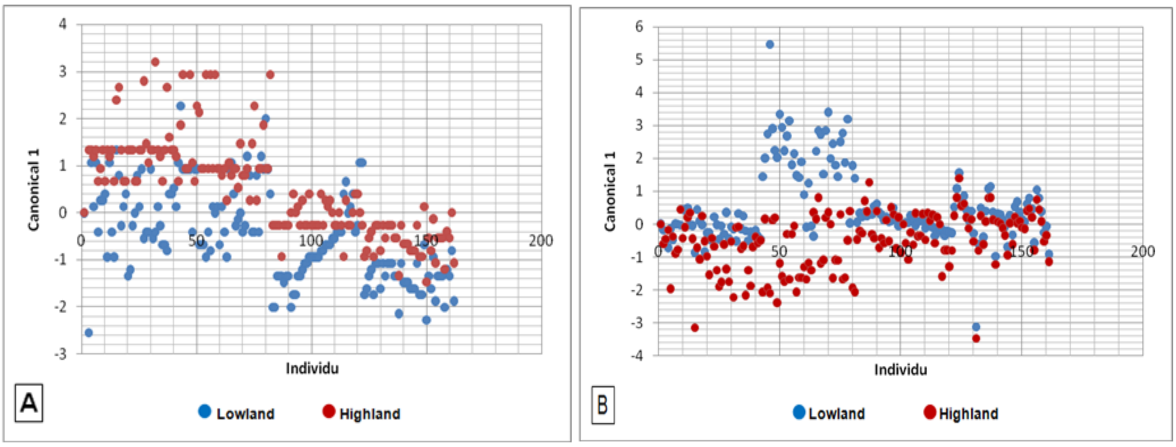

Figure 6. Canonical discriminant plot in the body measurements (A) and body indices (B) to characterize of Thin-tail sheep at two different areas

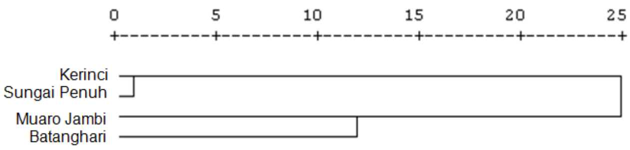

Figure 7. Dendogram distances among four different populations of Thin-tail sheep based on body weight, body measurements, and body indices.

al., 2018). Highly variable rainfall may negatively affect plant nutrient uptake and storage, potentially limiting plant growth during the growing season (Barbosa *et al*., 2014). Highly variable rainfall may negatively affect plant nutrient uptake and storage, potentially limiting plant growth during the growing season (Barbosa *et al*., 2014). Warmer regions with high temperatures are associated with lower quality forage grasses, containing higher proportions of fiber and lower proportion of crude protein, which are generally tougher to digest (Lee, 2018). Lee *et al*. (2017) reported that the increasing temperatures are associated with grasses of lower nutritive value, delivering higher concentrations of fibre, lower protein and lower dry matter digestibility of some forages. Argüello-Rangel *et al.* (2020) that forage plants in the lowlands get full sun radiation to greater the crude fiber content and lower the protein content.

Table 10. Euclidean distance between Thin-tail sheep from different populations based on body weight, body measurements, and body indices

Population	Kerinci	Sungai Penuh	Muaro Jambi	Batanghari
Kerinci	0.00	12.70	49.51	71.04
Sungai Penuh	-	0.00	32.05	56.38
Muaro Jambi	-	-	0.00	30.33
Batanghari	-	-	-	0.00

Schneider *et al*. (2019), Sorghum plants tend to experience a decrease in crude protein as a result of increasing the intensity of sunlight. It can be noticed, especially in the plants without cutting, which developed its normal cycle, that the gross protein values decrease as the crop cycle advances. This happens because the vegetative stage has a higher leaf proportion and younger tissue since gross protein values decreased in older tissues.

The population of Thin-tail sheep at lowland areas and highland areas includes of meaty and longline types of animal. Esquivelzeta *et al*. (2011) reported that the average of DTI and BI in Ripollesa sheep were 9.60±0.70 and 83.90±6.10, respectively, and included light and brevigline types of animal. Cerqueira *et al.* (2011) reported that the averages of DTI and BI values in Portuguese Bordaleira de Entre Douro e Minho (PBEDM) sheep were 8.88-9.84 and 80.37-84.25, respectively, and included light and brevigline types of animal. In addition, according to DTI value, the Pramenka sheep included light type of animal (DTI= 8.05-9.31) as reported by Markovic *et al.* (2019). The BW of Thin-tail sheep in this study was lower than those of Ripollesa (51.40±6.63 kg), Djallonke (21.70±0.50 kg), Sahel (27.50 ±0.80 kg), Zulu (34.70±0.20 kg), Morada Nova (31.74±5.09 kg), Balami (60.87±14.31 kg), Koroji (64.12±16.42 kg), Uda (57.83±17.76 kg), Yankasa (51.09±8.47 kg), Sohagi (48.20±1.73 kg), Rampur-Bushair (25.72±0.16 kg), Istrian Pramenka (61.29±0.90 kg), and PBEDM (32.92±5.05 kg) sheep (Esquivelzeta *et al.*, 2011; Birteeb *et al.*, 2012; Mavule *et al.*, 2013; Silva *et al.*, 2015; Dauda *et al.*, 2018; Elsaid & Elnahas, 2019; Sankhyan *et al.*, 2018; Markovic *et al.*, 2019; Cerqueira *et al.*, 2019). Purwanti *et al.* (2019) reported body index of Ettawa Grade does of Indonesia did not affect the litter size. The results of the study, chest girth significantly affects ($p<0.05$) body weight. The variation in BW could be due to breeds, management, or the environment. The productivity of sheep is affected by many factors, such as breed (genetic) and environmental factors (Petrovic *et al*., 2011).

Phenotypic Correlation

The correlation value between BW and CG in Thin-tail sheep at highland areas included of the high category ($0.61 < r < 0.80$) and similar to Uda (0.74-0.83) and Zulu (0.74) sheep (Yakubu & Akinyemi, 2010; Mavule *et al.*, 2013). Moderate category of r value ($0.40 < r < 0.60$) between BW and CG were reported in Rampur-Bushair (0.47) and Sohagi (0.55) sheep (Sankhyan *et al.*, 2018; Elsaid & Elnahas, 2019). Very high category of r value ($0.81 < r < 1.00$) between BW and CG were reported in Morada Nova (0.93) and Pramenka (0.87) sheep (Silva *et al.*, 2019; Markovic *et al.*, 2019). The different results of this study compared to previous studies can be caused by genetic (breed), management, and environmental factors. Indriani *et al.* (2020) reported that the cellulose and hemicellulose contents of grass at highland areas were lower than in lowland areas ($p<0.05$). Moreover, the fat deposit in sheep in lowland areas was lower than in sheep in highland areas because of high temperatures. Less fat deposit in sheep in lowland areas is important to reduce body temperature. Therefore, a low correlation between BW and CG in sheep in lowland areas may be caused by less fat deposit. Other factors that cause differences in the characteristics of sheep at the highland and lowland areas were the species and quality of forage consumed by the sheep. Forage in the lowlands will undergo a ripening process earlier than in the highlands, causing a decrease in forage quality due to an increase in cell walls, which are the main component of crude fiber. The crude fiber content in mature plants tends to increase, even in certain plants, it exceeds the increase in crude fiber in other plants (Nelson & Moser, 1994). Moreover, the fat deposit in lowland sheep was lower than in highland sheep because of the high temperature. Thus, less fat deposit in the lowland sheep is important to reduce body temperature. So, a low correlation between BW and CG in lowland sheep may be caused by less fat deposit.

Table 5 shows that the quality of forage consumed by thin-tail sheep in the lowland areas is lower than that of forage consumed by thin-tail sheep in the highland areas. The averages forage CP and EE contents consumed by sheep in the highland areas are higher than those consumed by the thin-tail sheep in the lowland areas. In contrast, thin-tail sheep's CF and Ash contents at highland areas are lower than those at the lowland areas. Turral *et al*. (2011) stated that the temperature was higher in the lowlands and medium areas, resulting in higher cellulose and hemicellulose content than in the highlands area. Plants in the highland areas develop with lower light intensity and air temperature so that protein quality is higher and is inversely proportional to its fiber content. Rochana *et al*. (2016) stated that forage plants in the lowlands get full sun radiation to greater the crude fiber content. Furthermore, it was also stated that the content of NDF, cellulose, and hemicellulose in the lowland areas and medium-land areas were higher than in the highland areas (Indriani *et al*., 2020). The higher the increase in crude fiber content, the higher the decrease in nutritional value (Setiyaningrum *et al*., 2018). Crude fiber content will affect feed digestibility in ruminants. The higher the crude fiber content, the lower the feed digestibility (Rustiyana *et al*., 2016). Based on the description above, it can be stated that the altitude influences the quality of forage.

Principal Component Analysis

The PCA of body measurements in Thin-tail sheep revealed that thin-tail sheep at lowland areas had 3 PC's and thin-tail sheep at highland areas had 2 PC's (Table 4). The PCA of body measurements was accounted to 72.30% in thin-tail sheep at lowland areas and 65.84% in thin-tail sheep at highland areas of the total variance in animal morphometrics. The determinant of body sizes that significantly different ($P<0.01$) and the highest in thin-tail sheep at the lowland areas and highland areas is the withers height, while the determinant of the shape in the thin-tail sheep at highland areas and lowland areas is shoulder width. Therefore, the PCA of body indices in Thin-tail sheep at lowland areas had 4 PC's and thin-tail sheep at highland areas with 5 PCs (Table 5). The PCA of body indices were accounted 78.23% in thin-tail sheep at lowland areas and 84.99% in thin-tail sheep at highland areas of the total variance in animal morphometrics. Previous studies obtained PCA of body measuements with accounting in total variance of about 59.00% (with 2 PC's) in Ripollesa sheep (Esquivelzeta *et al.*, 2011); 70.47% (with 2 PC's) in PBEDM sheep (Cerqueira *et al.*, 2011); 87.19% (with 2 PC's) in Ghanaian sheep (Birteeb *et al.*, 2012); 62.13% (with 4 PC's) in Zulu sheep (Mavule *et al.*, 2013); 75.21% (with 3 PC's) in Yankasa sheep (Yakubu, 2013); 66.91% (with 2 PC's) in Balami sheep (Yunusa *et al.*, 2013); 57.43% (with 2 PC's) in Uda sheep (Yunusa *et al.*, 2013); 72.28% (with 3 PC's) in Morada Nova sheep (Silva *et al.*, 2015); 61.53% (with 4 PC's) in Rampur-Bushair sheep (Sankhyan *et* *al.*, 2018); 57.80% (with 2 PC's) in Sohagi sheep (Elsaid & Elnahas, 2019); 96.65% (with 3 PC's) in Pramenka sheep (Markovic *et al.*, 2019), and 68.04% (with 3 PC's) in Djallonke sheep (N'Goran *et al.*, 2019). Unfortunately, the study of the PCA of body indices so far has not been reported. However, previous studies reported that PCA of body indices was accounted 86.84% (with 4 PC's) in Katjang does and 89.38% (with 4 PC's) in Pasundan cow (Putra & Ilham, 2019; Putra *et al.*, 2020). Malewa *et al.* (2008) reported the main characteristic variable of body size for local hammer sheep was chest circumference. Furthermore, Gunawan *et al*. (2011) also reported the characteristic measure that has a positive correlation with the size score is the chest circumference of all types of Indonesian Garut sheep. This study indicates that CG can be used as a selection parameter to increase the body size score of Thin-tail sheep both in the highland areas and lowland areas in Jambi Province.

The KMO values in PCA of body measurements were higher than PCA of body indices. According to the KMO value, PCA of body measurements in Thin-tail sheep at lowland areas and highland areas were accurate (KMO > 0.50). Hence, the KMO values in PCA of body indices in Thin-tail sheep at the highland area were not accurate (KMO < 0.50). The component plots of Thin-tail sheep's body measurements and body indices were illustrated in Figure 4 and Figure 5, respectively. Garut sheep is one Indonesian native Thin-tail sheep with registered breeds standard (SNI) based on age, BW, WH, BL, CG, and scrotum circumference (for male). Those parameters were classified into the first component for lowland and highland sheep.

Canonical Discriminant Analysis

Previous studies reported that the body measurements could be used to characterize 70%-100% of Ripollesa sheep at nine different populations (Esquivelzeta *et al.*, 2011); 54.18%-74.59% of Algerian sheep at three different populations (Dekhili, 2014) and 76.27%-92.80% of Djallonke ewes at three different populations (N'Goran *et al.*, 2019). Moreover, the body measurements were used by Asamoah-Boaheng & Sam (2016), reporting that 65.20% of Djallonke sheep, 88.90% of Sahel sheep, and 79.30% of Djallonke × Sahel sheep can be characterized with body measurements. The classification percentage in this study was lower than previous studies and needed more morphometric measurements. The cephalic measurements are important to obtain CDA. Popoola & Oseni (2018) obtained four cephalic measurements of skull width, head width, head length, and head depth as the describing variable to characterize four Nigerian sheep breeds. Moreover, Asamoah-Boaheng & Sam (2016) obtained head width and face length as the describing variable in three African sheep breeds. Meanwhile, Nunes *et al.* (2020) reported that about 57.1% (kept at Ceara region) and 54.5% (kept at Rio Grande do Norte region) of Marada Nova sheep could be classified into the original population based on their body indices. The difference in body measurements, presumably due to the differences in the environment, especially altitude. Indriani *et al.* (2020) stated that the content of NDF, cellulose, and hemicellulose in the lowlands and medium areas is higher than in the highlands. Increasing crude fiber content will reduce the nutritional value (Setiyaningrum *et al*., 2018). Crude fiber content will affect the feed digestibility in ruminants. The higher crude fiber content of feed will reduce the feed digestibility (Rustiyana *et al*., 2016). This study's rc value included moderate category and reveals that about 40% of lowland sheep and highland sheep can be classified with body measurements or body indices. Therefore, about 60% of both sheep may be classified by other factors such as phenotypic traits and genetic diversity.

Hierarchical Cluster Analysis

The HCA based on body weight, body measurements, and body indices revealed two clusters of highland clusters (Kerinci/KR and Sungai Penuh/SP Regencies) and two clusters of lowland clusters (Muaro Jambi/MJ and Batanghari/BA Regencies) as were illustrated in Figure 6. The lowest Euclidean distance showed in Kerinci-Sungai Penuh (12.70) and the highest showed in Kerinci-Batanghari (71.04), as presented in Table 8. Moreover, the Euclidean distance in Muaro Jambi-Batanghari (30.33) was closed to Muaro Jambi-Sungai Penuh (32.05). Previous studies obtained the Euclidean distance of 1.87 to 8.87 among Pramenka sheep from six different populations in Slovenia (Markovic *et al.*, 2019) and 2.34 to 7.77 among Black Creole goats from seven different populations in Mexico (Jarquin *et al.*, 2019). Therefore, Handiwirawan *et al.* (2011) obtained the Euclidean distance of 10.83 to 91.39 among five sheep breeds. Despite with morphometric, the phylogeny tree in the sheep can be obtained based on bloods profile (Geng *et al.*, 2003), mitochondrial DNA diversity (Mariotti *et al.*, 2013), and microsatellite locus (Jakaria *et al.*, 2012). The difference in animal management, selection, geographical area, agro-climatic conditions, and natural resources can affect the phenotypic variation in a breed in each population.

CONCLUSION

Five body measurements (BW, BL, WH, CD, and RH) and two body indices (TD and CI) were identified as the first component for explaining sheep morphometrics at lowland areas and highland areas. Around 67.5% of thin-tail sheep at lowland areas and 57.5% of thin-tail sheep at highland areas can be characterized with body measurements. Hence, about 61.2% thin-tail sheep at lowland areas and 65.6% thin-tail sheep at highland areas can be characterized with body indices. The cluster analysis in four Thin-tail populations revealed two clusters, i.e., cluster 1 (Kerinci and Sungai Penuh) and cluster 2 (Muaro Jambi and Batanghari). Around 60% of Thin-tail sheep can be characterized through their body indices to be used as a reference for selection and sheep breeding programs in the future.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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