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Morphometric characterization and zoometric indices of female Bali cattle reared in Lombok Tengah District, West Nusa Tenggara, Indonesia

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[2]Research Center for Applied Zoology, National Research and Innovation Agency, Cibinong Science Center. Jl. Raya Jakarta-Bogor Km. 46, Cibinong, Bogor 16915, West Java, Indonesia

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Abstract. *Warman AT, Fadhilah GT, Ibrahim A, Atmoko BA, Baliarti E, Panjono. 2023. Morphometric characterization and zoometric indices of female Bali cattle reared in Lombok Tengah District, West Nusa Tenggara, Indonesia. Biodiversitas 24: 966-974.* Livestock body conformation can be described by using their morphometric characteristics and zoometric indices. This study aims to provide information about female Bali cattle's (*Bos javanicus*) morphometric characterization and zoometric indices using principal component analysis (PCA). The study was conducted by using 149 heads of the female Bali cattle reared by smallholder farmers in Lombok Tengah District, West Nusa Tenggara Province, Indonesia. Morphometric characteristics in this study consists of body length (BL), withers height (WH), chest girth (CG), chest width (CW), chest depth (CD), rump height (RH), rump width (RW), head length (HW), and head width (HW). Therefore, the zoometric indices in this study consist of body index (BI), body ratio (BR), cephalic index (CeI), compact index (CoI), conformation index (CnI), depth index (DI), index of compression (IC), height index (HI), height slope (HS), length index (LI), over increase index (OII), thoracic development (TD), transverse pelvic (TP), and weight (W). Data were analyzed by descriptive analysis and factor analysis (principal component analysis/PCA) using SPSS 25.0 program. The average body measurements for BL, WH, CG, CW, CD, RH, RW, HL, and HW were 108.40, 108.35, 148.54, 34.54, 57.50, 106.28, 32.03, 34.66, and 19.10 cm, respectively. The highest correlation coefficient (r) in morphometric characteristics was shown between RH and WH (0.744) and in zoometric indices between BR and HS (0.997). The PCA for morphometric characteristics revealed two factors of PC1 (BL, CG, CW, CD, RW, and HL) and PC2 (WH, RH, and HW), which explain about 67.50% of the total variation. The PCA for zoometric indices revealed four factors of PC1 (CoI, CnI, DI, LI, TD, TP, W), PC2 (BR, HS, and OII), PC3 (BI, IC), and PC4 (CeI), which explain about 90.64% of the total variation. It was concluded that six morphometric characteristics (BL, CG, CW, CD, RW, and HL) were important to describe the body conformation of female Bali cattle and could be used as selection criteria.

Keywords: Bali cattle, body measurement, factor analysis, Indonesian cattle, zoometric indices

INTRODUCTION

Bali cattle are native Indonesian livestock resources. Bali cattle are widely reared due to their good adaptability to Indonesia's environment (Widyas et al. 2022). Bali cattle are spread throughout Indonesia, especially on the islands of Bali, South Sulawesi, East Nusa Tenggara, and West Nusa Tenggara. The population of Bali cattle in Indonesia is recorded at 4,789,521 heads, or 32% of the total population of beef cattle, and 492,000 of them are in West Nusa Tenggara Province. The high population of Bali cattle spread throughout all regions in Indonesia proves that Bali cattle can adapt well and are suitable to be kept and reared by farmers as a meat-producing livestock commodity (Hikmawaty et al. 2014). The high population of Bali cattle in West Nusa Tenggara, especially in Lombok Tengah District, has the potential to be developed outside Bali Island. However, from various information, it was found that Bali cattle outside Bali Island showed a decline in genetic quality caused by negative selection and improper rearing management. One of the indicators of this decrease can be seen in body weight and linear body size. Of the four locations, Bali, East Nusa Tenggara, West Nusa Tenggara and South Sulawesi, each site shows quite diverse differences (Hikmawaty et al. 2014; Budisatria et al. 2021; Widyas et al. 2022).

Phenotypic characteristics in the form of body size describe a growth process that occurs from birth to body maturity. The measurement of phenotypic traits is an important indicator for assessing an animal because it is related to its genetic potential and economic impact (Gushairiyanto and Depison 2021). Phenotypic characteristics are used to measure and describe the genetic diversity of existing resources (FAO 2012). In addition, measurements of phenotypic traits can be used to facilitate selection between purebred breeds and crosses, characterization of cattle, and body measurements obtained can also be used for body weight estimation (Gushairiyanto

and Depison 2021; Ibrahim et al. 2022a). Several body measurements for cattle are used to characterize, namely withers height, chest width, chest girth, rump height, rumpt width, head length, head width, ear length, ear width, and horn length (Sharma et al. 2013; Islam et al. 2022)

Morphological traits can describe the characteristics of a breed (Ibrahim et al. 2022a). Body size has been used to indicate an individual's type, origin, and relationship because it gives an idea of the body's conformation (Rahmawati et al. 2022). One of the analyzes that can be used to see the relationship between body size is principal component analysis (PCA). Principal component analysis (PCA) is an analysis tool to explain the relationship between biometric properties (Tolenkhomba et al. 2021). Principal component analysis (PCA) is an analysis that can explain the relationship between body size that can determine body size characteristics. Some researchers also use PCA to characterize carcasses by performing morphometric measurements (Slimene et al. 2012; Sarma 2022). Characterization of cattle breeds can provide information that will be used in making decisions about the development of cattle breeding programs and their practical use. It is also used to design proper management for that breed of cattle. In addition, characterization can also be used as a selection criterion in cattle breeding programs (Putra et al. 2020; Okoh et al. 2021)

This PCA analysis has been carried out on livestock in Indonesia, including Swamp buffalo (*Bubalus bubalis*), Pasundan cattle, Taro White cattle (*Bos javanicus*), Batur and Wonosobo sheep (*Ovis aries*), and Katjang goat (*Capra aegagrus hircus*) (Heryani et al. 2018; Putra and Ilham 2019; Putra et al. 2020; Ibrahim et al. 2022a; Putra and Hilmawan 2022). However, in Bali cattle in Lombok Tengah District, West Nusa Tenggara, PCA analysis has never been carried out using body size data. Therefore, this study aimed to perform PCA on female Bali cattle using body size data to characterize Bali cattle as criteria for selection.

MATERIALS AND METHODS

Ethical clearance

This research has been approved by the Research Ethics Commission, Faculty of Veterinary Medicine, Universitas Gadjah Mada, Yogyakarta (No:00018/EC-FKH/EKs/2021).

Study area and animal

This research was conducted in three sub-districts with high (Jonggat), medium (Pringgarata), and low (Batukliang) population categories in Lombok Tengah District, West Nusa Tenggara Province, Indonesia (Figure 1). Body size data were taken from 149 heads of female Bali cattle aged 2 to 6 years (average 3.97 years old). The cattle were selected by purposive sampling with the condition that the cattles were mature, non-pregnant and had replaced 1 to 4 pairs of incisors. The breeds of cattle were identified visually, and then their ages were known through direct interviews with farmers.

Morphometric characterization and zoometric indices

Nine morphometric characteristics (body measurements) are body length (BL), withers height (WH), chest girth (CG), and chest depth (CD) (Widi et al. 2016); rump heigth (RH) and rump width (RW) (Putra et al. 2020); chest width (CW), head length (HL) and head width (HW) (Heryani et al. 2018). Body measurements are measured with a measure stick, including body length, withers height, hip height, hip width, chest width, and chest depth.

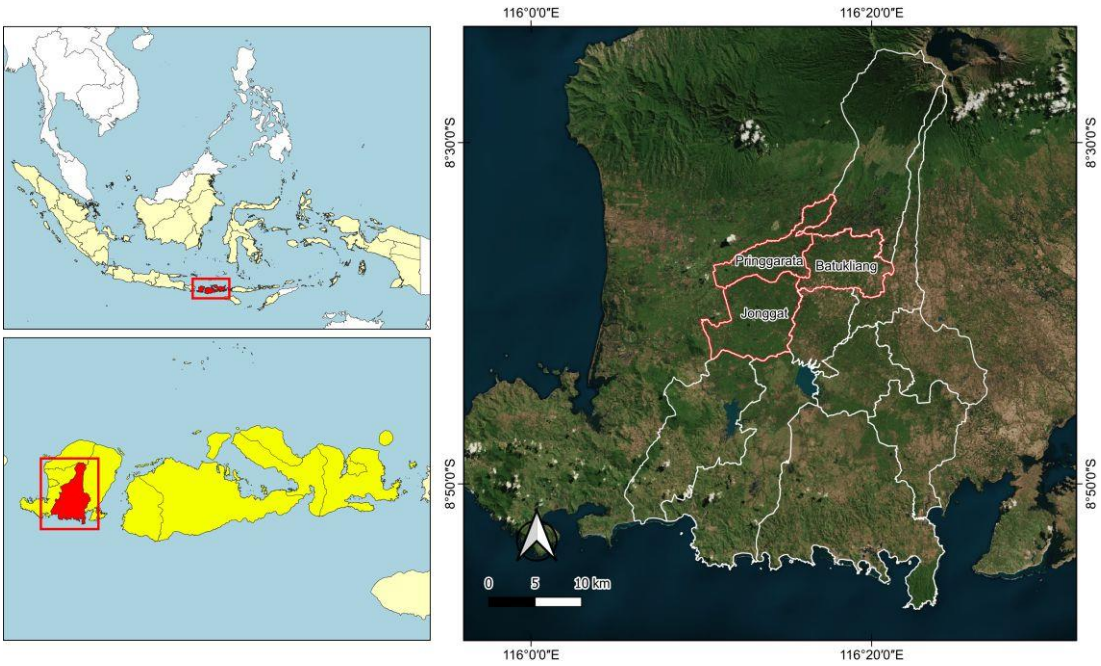

Figure 1. The sampling sites of this study in Jonggat, Pringgarata, and Batukliang of Lombok Tengah District, West Nusa Tenggara Province, Indonesia

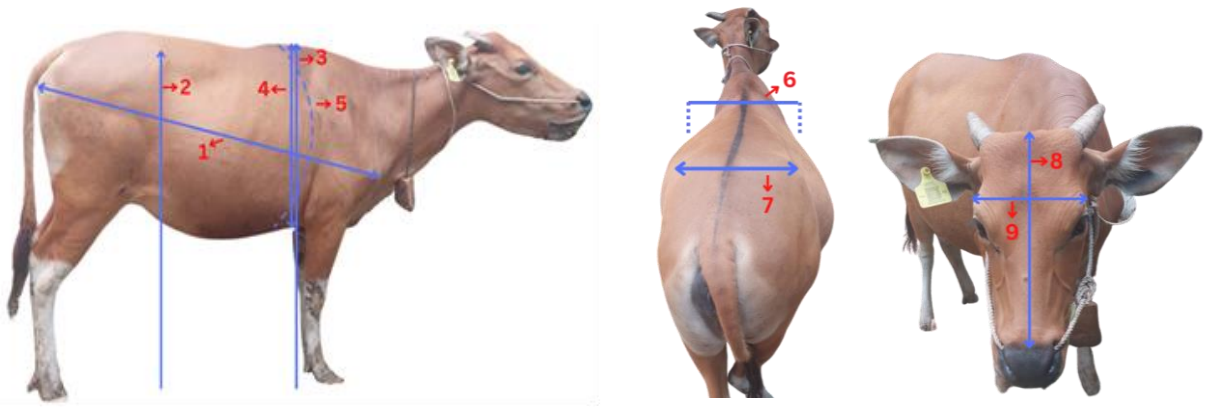

Figure 2. The scheme of the body measurements in Bali cows consisted of body length (1), withers height (2), chest girth (3), chest depth (4), chest width (5), rump height (6), rump width (7), head length (8), head width (9)

Table 1. The formula for zoometric indices* analysis in cattle

Zoometric indices	Symbol	Formula
Body index	BI	(BL/CG) x 100
Body ratio	BR	WH/RH
Cephalic index	CeI	(HW/HL) x 100
Compact index	CoI	W/WH
Conformation index/Baron and Crevat	CnI	(CG^2)/WH
Depth index/relative depth of thorax	DI	CD x WH
Index of compression	IC	(CG/BL) x 100
Height index/Proportionality	HI	(WH/BL) x 100
Height slope	HS	WH – RH
Length index	LI	BL/WH
Over increase index	OII	(RH/WH) x 100
Thoracic development	TD	CG/WH
Transverse pelvic	TP	(RW/RH) x 100
Weight (Lambourne)	W	$((CG^2)$ x BL)/10840

Note: *Khargharia et al. (2015); Banerjee (2017); Putra et al. (2020); Ibrahim et al. (2022a)

In contrast to the chest girth, head length and head width are measured with a measuring tape. Body weight of cattle is estimated using the Lambourne formula. All the measurements were recorded once on an upright animal standing on level ground (Figure 2). Next, fourteen zoometric indices parameters were calculated using a formula according to Khargharia et al. (2015), Banerjee (2017), and Putra et al. (2020), as presented in Table 1.

Data analysis

Morphometric characteristics (BL, WH, CG, CD, Cw, RH, RW, HL, and HW) and zoometric indices (BI, BR, CeI, CoI, CnI, DI, IC, HI, HS, LI, OII, TD, TP, and W) were analyzed descriptively (mean, standard deviation, coefficient of variation, minimum, and maximum). The morphometric characteristics and zoometric indices data were also analyzed using factor analysis (principal component analysis/PCA) performed by using the SPSS 25.0 program.

RESULTS AND DISCUSSION

Morphometric characterization

This study indicates that moderate coefficient of variation (CV) values (0.10<CV<0.20) in morphometric traits are found in CW, RW, and HW. In contrast, other morphometric traits have low CV values (CV<0.10), as presented in Table 2. Body measurements can be used to assess livestock characteristics. Body measurements are an important source of data in that they reflect breed standards and provide information on livestock's morphological structure and developmental capabilities (Musa et al. 2012). The coefficient of variation in female cattle's morphometricis divided into three categories, namely low (CV<10%), medium (10%<CV<20%) and high (CV>20%). In this study, the morphometric of the Bali cattle has a different coefficient than the Pasundan cattle. In Pasundan cattle, the CW, RW, BL, and RL have coefficients of variation that are categorized into the medium category (0.10<CV<0.20) (Putra et al. 2020). The coefficient of variation in morphometric of Nguni cattle was categorized into low (HW, RH) and medium (HL, BL, WH, RW, CG) categories (Tyasi and Putra 2022). In Kedah-Kelantan cattle, the WH and RH sizes are in the low category, while other body sizes are in the medium category (Islam et al. 2022).

In Lombok Tengah District, the average withers height (WH) of adult female Bali cattle was higher than Bali cattle in Jambi (103-105 cm) (Depison et al. 2022). However, it is lower than Bali cattle in Banyumulek Techno Park West Nusa Tenggara Province (111-126 cm) (Agung et al. 2018), and Pasundan cattle in West Java (116-122 cm) (Said et al. 2017). The body length (BL) of the Bali cattle in this study was longer than that of the Bali cattle in Jambi (100-104 cm) (Depison et al. 2022) but shorter than Bali cattle on Bali Island (119 cm) (Hikmawaty et al. 2014), Bali cattle on Southeast Sulawesi Province (110.16 cm) (Hafid 2020), Pasundan cattle (109-125 cm) (Said et al. 2017), and Madura cattle (127-135 cm) (Prihandini et al. 2020). The average chest girth (CG) of Bali cattle in this study was larger than Bali cattle in Sumatra (145 cm) (Lindell 2013)

and Galekan cattle (140-145 cm) (Kuswati et al. 2022). However, it is smaller than Bali cattle in Kalimantan (154 cm) (Lindell 2013) and Madura cattle (160 cm) (Herviyanto et al. 2021).

The chest depth (CD) of Bali cattle in Lombok Tengah District was larger than that of Bali cattle in Jambi (43-45 cm) (Depison et al. 2022). The chest width (CW) in this study was greater than that of Bali cattle in the Merangin District (30.88 cm) and Muaro Jambi District (30.66 cm) (Gushairiyanto and Depison 2021). The rump height (RH) of Bali cattle in Lombok Tengah is higher than that of Kedah-Kelantan cattle (101.5 cm) (Islam et al. 2022). However, it is lower than Nguni cattle (127.49 cm) (Tyasi and Putra 2022), and Jabres cattle (119.15 cm) (Adinata et al. 2016). The rump width (RW) of Bali cattle in this study was lower than that of Bali cattle in the Merangin District (33.85 cm) and Muaro Jambi District (33.60 cm) (Gushairiyanto and Depison 2021), but similar to Jabres cattle (31.67 cm) (Adinata et al. 2016).

The head length (HL) of Bali cattle in Lombok Tengah District was shorter than that of Bali cattle in Kupang (35.87-36.62 cm) (Tabun et al. 2022) and Kedah-Kelantan cattle (38.70 cm) (Islam et al. 2022). In addition, the head width (HW) of the Bali cattle in Lombok Tengah District was longer than that of the Bali cattle in Kupang (15.25-16.59 cm) (Tabun et al. 2022) and the Kedah-Kelantan cattle (14.00 cm), but shorter than the head width of the Nguni cattle (21.73 cm) (Tyasi and Putra 2022). Differences in morphological traits are related to breed, climatic conditions, and geographical location. Morphometric variations show livestock's adaptability to existing production and management systems (Wibowo et al. 2021; Islam et al. 2022).

Zoometric indices

The descriptive statistics for all zoometric indices (body indices) are presented in Table 2. Therefore, the high CV values (CV>0.20) in zoometric indices were found in HS and W. The zoometric indices of BI, CeI, CoI, CnI, and TP had moderate CV values (0.10<CV<0.20), and the other had low CV values. In Pasundan cattle, it was found that zoometric indices with high (HS, RLI, TP), medium (WS, BI, AI, CI, PI, LP), and low (LI, BR, Proportionality, TD) values. Pasundan cattle have CV in BR, HS, and LI of 0.97, 3.79, and 1.01, respectively (Putra et al. 2020). Bali cattle in this study had a higher BR than Pasundan cattle but a lower CV in HS and LI.

In this study, the zoometric indices of female Bali cattle include WI, LI, and OII lower than Malle cattle, namely 229.42±2.95; 1.10±0.01; and 99.44±0.35, respectively. Meanwhile, HI, HS, DI, and TD were higher than Malle cattle, namely 91.81±0.45; 0.83±0.35; 0.50±0.00; 1.26±0.01, respectively. Then the body ratio (BR) has almost the same value between Bali cattle and Malle cattle, namely 1.01±0.00 (Getaneh et al. 2019). Different things were found in Bali cattle which had a higher conformation index (CI) (204.72±29.38) than in Pasundan cattle which had a conformation index (CI) (157.26±22.76) (Putra et al. 2020).

Table 2. Descriptive statistic of morphometric characteristics and zoometric indices in female Bali cattle

Parameters	Mean	SD	CV (%)	Min.	Max
Morphometric characteristics					
Body length (BL)	108.40	8.12	7.49	84.00	129.00
Withers height (WH)	108.35	6.10	5.63	89.00	124.00
Chest girth (CG)	148.54	12.37	8.33	112.00	174.00
Chest width (CW)	34.34	4.05	11.79	23.00	43.00
Chest depth (CD)	57.50	5.14	8.94	43.00	68.00
Rump height (RH)	106.28	5.63	5.30	86.00	119.00
Rump width (RW)	32.03	3.66	11.43	21.00	40.00
Head length (HL)	34.66	3.16	9.12	21.00	42.00
Head width (HW)	19.10	2.41	12.62	12.00	24.00
Zoometric indices					
Body index (BI)	73.18	4.70	6.42	61.15	92.50
Body ratio (BR)	1.02	0.04	3.92	0.87	1.11
Cephalic index (CeI)	55.36	7.46	13.48	39.39	88.46
Compact index (CoI)	2.06	0.39	18.93	1.07	3.09
Conformation index (CnI)	204.72	29.38	14.35	128.57	279.45
Depth index (DI)	0.53	0.04	7.55	0.43	0.65
Index of compression (IC)	137.21	8.87	6.46	108.11	163.54
Height index (HI)	100.29	6.49	6.47	84.17	119.78
Height slope (HS)	2.07	3.97	191.79	-13.00	11.00
Length index (LI)	1.00	0.06	6.00	0.83	1.19
Over increase index (OII)	98.18	3.72	3.79	90.00	114.44
Thoracic development (TD)	1.37	0.10	7.30	1.07	1.66
Transverse pelvic (TP)	30.14	3.15	10.45	20.79	37.11
Weight (W) (Lambourne)	223.96	47.08	21.02	99.52	335.16

Phenotypic correlations

Pearson's coefficient of correlation (r) among all morphometric characteristics shows that BL-CD, CG-CD, and WH-RH were positive and high (0.70<r<0.90), as presented in Table 3. Meanwhile, the correlations among all zoometric indices show that BI-CoI, CoI-CnI, BR-HS, BI-W, CoI-W, and CnI-TD were positive and very high (r>0.90) as presented in Table 4. Thus, the correlation of HS-TD, BR-OII, and HI-LI was negative and very high (r>0.90).

Bali cattle in this study had positively correlated and high body sizes on CD-CG (0.79), RH-WH (0.74), and CD-BL (0.72) (Table 3). The correlation value obtained is different from that of Bali cattle in Jambi Province, which has the highest correlation coefficient value in the lowland areas, namely RH-WH (0.85) and RH-CG (0.85) while in the midland area, it is obtained at BL-CG (0.91) (Depison et al. 2022). Meanwhile, the correlation value of body size in Kedah-Kelantan cattle in Malaysia is highest at Wither Height (WH) - Hip Height (HH) (0.91), Wither Height (WH) - Heart Girth (0.81) (Islam et al. 2022). The highest correlation value in Nguni cattle is RH-CG (0.74) (Tyasi and Putra 2022). Meanwhile, the correlation value for body size in Inyambo cattle in Rwanda, which has a high correlation, is Heart Girth (HG) - Body Weight (BW) (0.98), Horn Length (HL) - Body Length (BL) (0.74), Height at Withers (HW) - Heart Girth (HG) (0.71) (Hirwa et al. 2017).

Principal component analysis

The adequacy of Kaiser-Meyer-Olkin (KMO) sampling shows the proportion of variance in different body sizes caused by various underlying factors (Tolenkhomba et al. 2012). The KMO values in this study were 0.891 (body size) and 0.664 (body index), with the significance of the Bartletts test value (P<0.01) (Table 5). Accurate PCA results are indicated by KMO>0.05 with a significant Bartletts test. The KMO value in this study was higher than that of Putra et al. (2020) on Pasundan cattle (0.72) and Tyasi and Putra (2022) on Nguni cattle (0.74).

The PCA of morphological characteristics (body measurements) in this study obtained two principal components (PC) (Eigenvalue>1), as presented in Table 5 and Figure 3. Projections on principal component analysis (PCA) of the factors and associations between body measurements in female Bali cattle were illustrated in Figure 4. According to Table 5 and Figure 4, the first component (PC1) was explained as 56.12% of the total variance and composed of the main components of BL, CG, CW, CD, RW, and HL. The second component (PC2) was explained as 11.35% of the total variance and consisted of the main components of WH, RH, and HW. Morphometric traits' principal components explained 67.50% of the total variance (Table 5).

The first component describes the body size that is common in Bali cattle. Previous studies reported that the main component is body size which is commonly used for selection criteria of beef cattle (Verma et al. 2015; Putra et al. 2020). The variance of the main components in Pallaresa cattle is 65.8% with 2 PC (Parés-Casanova et al. 2013); Pasundan cattle is 89.38% with 2 PC (Putra et al. 2020); local cattle in the Himalayas is 65.9% with 5 PC; and Nguni cattle is 68.12% with 3 PCs (Tyasi and Putra 2022).

Size markers (PC1) in Taro cattle are BL, WH, and RH, while a shape marker (PC2) is CD (Heryani et al. 2018). In Pasundan cattle, seven body sizes were found, which became the main components, including WH, BL, RH, CG, CW, RW, and RL (Putra et al. 2020). The main components in Nguni cows are three contributing factors, including the first factor (PC1), namely face width (FW), body length BL, rump height (RH), and withers height (WH); the second factor (PC2) are face length (FL), ear length (EL) and rumpt width (RW); the third factor (PC3) are sternum height and chest girth (CG) (Tyasi and Putra 2022).

The PCA of zoometric indices (body indices) in the present study obtained four principal components (Eigenvalue>1), as presented in Table 6 and Figure 3. Projections on principal component analysis (PCA) of the factors and associations between zoometric indices in female Bali cattle (PC1, PC2, PC3) were illustrated in Figure 5. The first component (PC1) was explained as 41.01% of the total variance and consisted of the main components of CoI, CnI, DI, LI, TD, TnP and W. The second component (PC2) explained 23.42% of the total variance and consisted of the main components of BR, HS, and OII. The third component (PC3) explained 18.91% of the total variance and consisted of the main components of BI and IC. The fourth component (PC4) was explained at 7.24% and consisted of the main component of CeI. Four body indices' principal components could explain 90.64% of the total variance (Table 6).

Table 3. Phenotypic correlation among morphometric characteristics in female Bali cattle

Parameter	BL	WH	CG	CW	CD	RH	RW	HL	HW
BL	1.000	-	-	-	-	-	-	-	-
WH	0.567**	1.000	-	-	-	-	-	-	-
CG	0.680**	0.521**	1.000	-	-	-	-	-	-
CW	0.484**	0.296**	0.610**	1.000	-	-	-	-	-
CD	0.725**	0.574**	0.799**	0.570**	1.000	-	-	-	-
RH	0.535**	0.744**	0.499**	0.287**	0.496**	1.000	-	-	-
RW	0.636**	0.473**	0.639**	0.564**	0.697**	0.430**	1.000	-	-
HL	0.457**	0.366**	0.440**	0.298**	0.453**	0.295**	0.437**	1.000	-
HW	0.491**	0.392**	0.476**	0.287**	0.448**	0.408**	0.406**	0.378**	1.000

Note: **P<0.01

Table 4. Phenotypic correlation among zoometric indices in female Bali cattle

Parameter	BI	BR	CeI	CoI	CnI	DI	IC	HI	HS	LI	OII	TD	TP	W
BI	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-
BR	0.020	1.000	-	-	-	-	-	-	-	-	-	-	-	-
CeI	-0.010	-0.096	1.000	-	-	-	-	-	-	-	-	-	-	-
CoI	-0.328**	-0.020	0.147*	1.000	-	-	-	-	-	-	-	-	-	-
CnI	-0.584**	-0.072	0.188	0.950**	1.000	-	-	-	-	-	-	-	-	-
DI	-0.212**	-0.124	0.60	0.684**	0.691**	1.000	-	-	-	-	-	-	-	-
IC	-0.994**	-0.007	0.010	0.315**	0.574**	0.211**	1.000	-	-	-	-	-	-	-
HI	-0.330**	0.232**	-0.094	-0.627**	-0.488**	-0.602**	0.348**	1.000	-	-	-	-	-	-
HS	0.019	0.997**	-0.095	-0.019	0.074	-0.128	-0.007	0.242**	1.000	-	-	-	-	-
LI	0.326**	-0.245**	0.083	0.627**	0.490**	0.607**	-0.343**	-0.996**	-0.255**	1.000	-	-	-	-
OII	-0.025	-0.997**	0.110	0.037	0.088	0.133	0.012	-0.242**	-0.997**	0.256**	1.000	-	-	-
TD	-0.581**	-0.234**	0.076	0.822**	0.928**	0.716**	0.567**	-0.570**	-0.242**	0.576**	0.248**	1.000	-	-
TP	-0.094	0.257**	-0.015	0.502**	0.468**	0.531**	0.094	-0.411**	0.249**	0.404**	-0.248**	0.425**	1.000	-
W	-0.299**	0.102	0.167*	0.969**	0.887**	0.581**	0.289**	-0.496**	0.108	0.492**	-0.085	0.678**	0.474**	1.000

Note: *P<0.05; **P<0.01

Table 5. Eigenvalues, total variance, cumulative, communalities, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity for the morphometric characteristics of female Bali cattle based on the rotated component matrix

Morphometric characteristics	PC1	PC2	Communalities
Body length	0.669*[a]	0.511	0.709
Withers height	0.249	0.876*[a]	0.830
Chest girth	0.789*[a]	0.385	0.771
Chest width	0.828*[a]	0.011	0.686
Chest depth	0.782*[a]	0.421	0.789
Rump height	0.188	0.892*[a]	0.830
Rump width	0.774*[a]	0.305	0.692
Head length	0.516*[a]	0.308	0.361
Head width	0.403	0.494*[a]	0.406
Eigenvalues	5.054	1.021	-
Variance (%)	56.150	11.350	-
Cumulative (%)	56.150	67.500	-
KMO		0.891	
Bartlett's test		**	

Note: PC= Principal component; *[a]main component; ** P<0.01

Table 6. Eigenvalues, total variance, cumulative, communalities, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity for the zoometric indices of female Bali cattle based on the rotated component matrix

Zoometric indices	PC1	PC2	PC3	PC4	Communalities
Body index	-0.177	0.025	-0.975[a]	0.006	0.982
Body ratio	-0.028	0.992[a]	0.003	-0.026	0.986
Cephalic index	0.069	-0.069	-0.016	0.970[a]	0.950
Compact index	0.931[a]	0.017	0.194	0.148	0.928
Conformation index	0.876[a]	-0.049	0.449	0.094	0.980
Depth index	0.815[a]	-0.109	0.067	-0.069	0.686
Index of compression	0.165	-0.012	0.978[a]	-0.006	0.985
Height index	-0.800	0.229	0.510	-0.012	0.953
Height slope	-0.033	0.993[a]	0.007	-0.021	0.988
Length index	0.800[a]	-0.243	-0.505	0.001	0.955
Over increase index	0.043	-0.991[a]	0.000	0.040	0.985
Thoracic development	0.841[a]	-0.237	0.410	-0.010	0.932
Transverse pelvic	0.654[a]	0.325	-0.032	-0.147	0.556
Weight	0.845[a]	0.153	0.203	0.211	0.823
Eigenvalues	5.749	3.279	2.647	1.014	-
Variance (%)	41.067	23.423	18.905	7.243	-
Cumulative (%)	41.067	64.490	83.395	90.638	-
KMO	0.631				
Bartlett's test	**				

Note: PC= Principal component; [a]main component; ** P<0.01

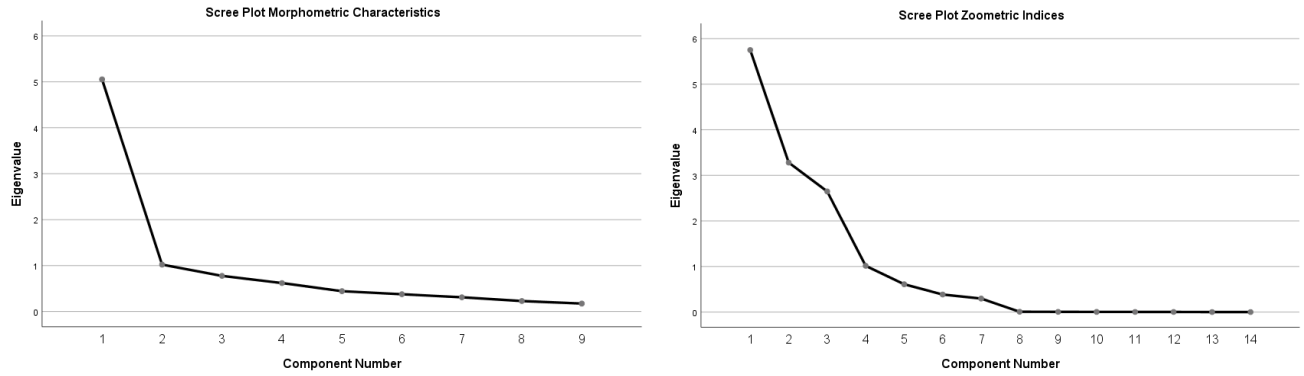

Figure 3. The scree plot of morphometric characteristics and zoometric indices in female Bali cattle

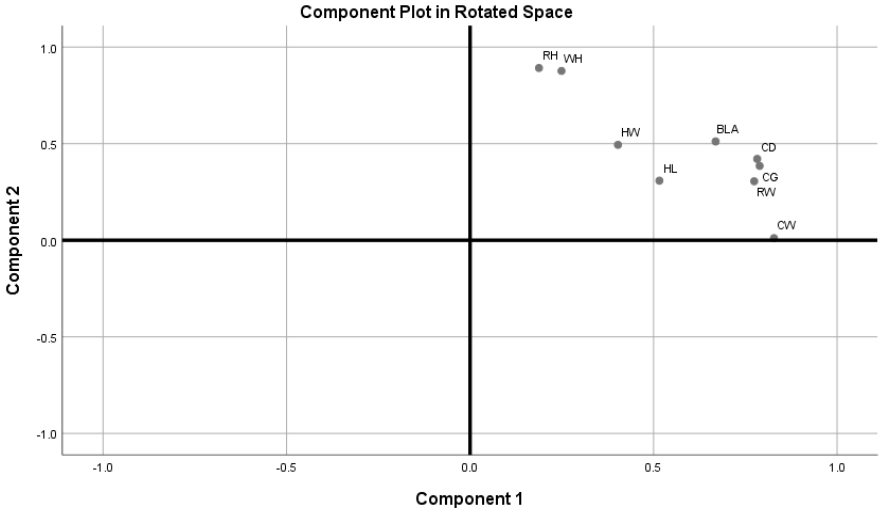

Figure 4. Projections on principal component analysis (PCA) of the factors and associations between morphometric characteristics in female Bali cattle based on the rotated component matrix

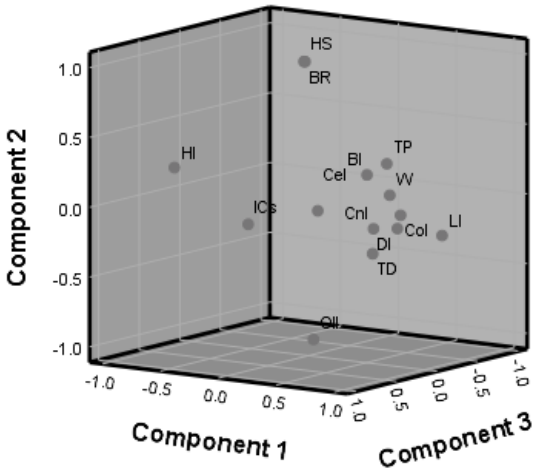

Figure 5. Projections on principal component analysis (PCA) of the factors and associations between zoometric indices in female Bali cattle based on the rotated component matrix (PC1, PC2, PC3)

Of the nine body sizes of Bali cattle that were measured, seven body sizes had a communality value of more than 0.50. The seven sizes are BL, WH, CG, CW, CD, RH and RW. Meanwhile, the HL and HW measures have a communality value of less than 0.50. Different things are shown in the communality value of the 14 body indices, which have a value of more than 0.50. Putra et al. (2020) stated that the communality value was more than 0.50, indicating that all body sizes and indices explained body conformation in cattle. Previous studies reported that the communality value was low (less than 0.50) in the body size of Oulmes-Zaer cattle (HL, horn length) and Tidili cattle (BL, cannon circumference, HL, horn length, and tail length) (Boujenane 2015). The difference in results compared to previous studies could be due to differences in body measurements, genetics, environment and geographical conditions, and rearing management (Ibrahim et al. 2022a, 2022b).

Based on the results of this study, six morphometric characteristics (body measurements) of BL, CG, CW, CD, RW, and HL are the first component to describe the body conformation in female Bali cattle. Therefore, two zoometric indices (body indices) based on these body measurements (BI and W) were the first components describing the body conformation in female Bali cattle. It was concluded that six body measurements of BL, CG, CW, CD, RW, and HL as the main measurements in female Bali cattle and can be used as the selection criteria.

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