

## PRINCIPAL COMPONENT ANALYSIS (PCA) OF BODY MEASUREMENTS IN MALE SWAMP BUFFALO (*Bubalus bubalis*) OF INDONESIA

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**ABSTRACT.** This study was carried out to determine principal component analysis (PCA) in 18 morphometrics of male swamp buffaloes (*Bubalus bubalis*) in the Central Java Province, Indonesia. A total of 44 animals were used in this study and separated into two groups of age i.e. 2PPI (2.0 - 3.5 years ages) with 24 animals and 3PPI (3.5 - 4.0 years age) with 20 animals. This study showed that five principal components (PC) of morphometric traits were found in both group and explained about 70% of the total variance in each ages group. Six morphometrics: *ossa vertebrae cervicale* length (OVCL), *ossa vertebrae thoracic* length (OVTL), *os humerus* length (OHL), *ossa radius ulna* length (ORUL), *os femoris* length (OFL), *ossa tibia-fibula* length (OTFL) were described as the first component (PC1) for 2PPI animals. Meanwhile, four morphometrics: *os metatarsals* length (OML), withers height (WH), chest depth (CD), hip height (HH) were showed as the PC1 for 3PPI animals. It was concluded that the general performance of WH, CD, HH can be used as morphometric selection criteria for swamp buffalo bulls at 3-4 years of age.

**Keywords:** PCA, PPI, morphometrics, swamp buffalo

### INTRODUCTION

In Indonesia, buffalo is one of the important livestock for meat production. The total buffalo population in Indonesia in the year 2017 reached 1,395,191 heads. Therefore, the number of slaughtered buffalo in the same year reached 126,000 heads [1]. The average adult weight and carcass percentage in Indonesian swamp buffalo managed in the feedlot system were  $218.66 \pm 16.28$  kg and  $46.49 \pm 1.95\%$  respectively [2]. Selection in buffalo can be performed with conventional and molecular methods. In the conventional method, selection of buffaloes were performed with some body measurements (morphometrics) records.

Thus, the buffalo's morphometrics can be used to describe body conformation or body dimension of an animal through Principal component analysis (PCA). Previous studies reported that PCA was performed in ruminant animals morphometrics such as cattle [3-11], buffalo [12-16], goat [17-22] and sheep [23-27]. Most buffaloes in Indonesia were kept in the smallholdings with an extensive management system. Commonly, the selection of buffalo in smallholdings based on body weight can not be applied because of weighing scales lacking in animal facilities. So, the PCA is important to obtain the main component in buffalo's morphometrics for the selection criteria. This research was carried

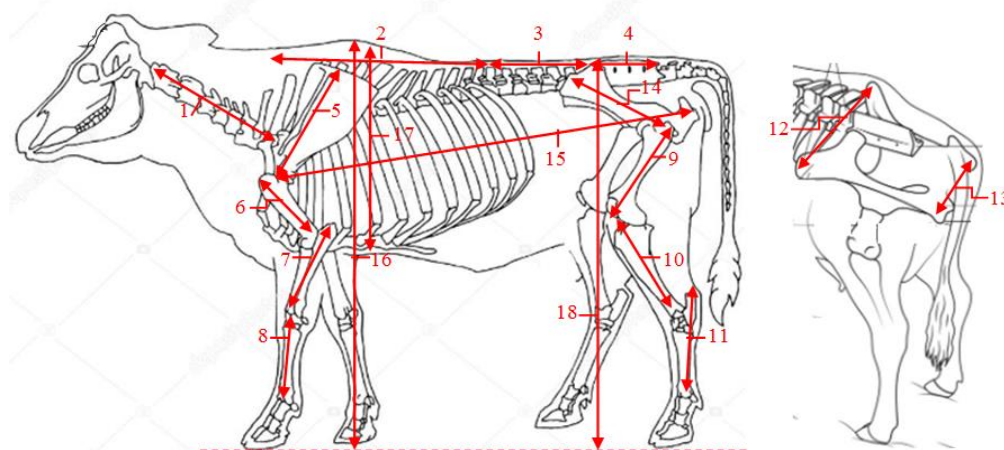
out to obtain the body conformation/dimension using the PCA method with 18 morphometrics of swamp buffalo bulls (*Bubalus bubalis*). The results in this study can be used as the early information to develop buffalo's selection program in smallholdings of Indonesia.

## MATERIALS AND METHODS

### *Animals*

A total of 44 heads of swamp buffalo bulls (*Bubalus bubalis*) from buffalo market center (BMC) in the Kudus Region of Indonesia were used in this study. The animals were separated based on the pairs of permanent incisors (PPI) groups of 2PPI (2.0 - 3.5 years age) and 3PPI (3.5 - 4.0 years age).

### *Animals Measurement*



**Fig 1.** The scheme of buffalo's morphometrics. 1:Ossa vertebrae cervicalis length; 2:Ossa vertebrae thoracicae length; 3:Ossa vertebrae lumbales length; 4:Ossa vertebrae sacrales length; 5:Os scapula length; 6:Os humerus length; 7:Ossa radius-ulna length; 8:Os metacarpale length; 9:Os femoris length; 10:Ossa tibia-fibulla length; 11:Os metatarsale length; 12:Coxae distance; 13:Ischium distance; 14:Coxae-Ischium distance; 15:Body length; 16:Withers height; 17:Chest depth; 18:Hip height

A total of 18 body measurements were performed in each animal as illustrated in Fig. 1. *Ossa vertebrae cervicalis* length (OVCL) was measured from the limit of *axio-atlas* to the end of the neck (1<sup>st</sup> dorsal vertebrae) or in front of hump. *Ossa vertebrae thoracicae* length (OVTL) was measured from end of the neck to middle point of the body (13<sup>th</sup> dorsal vertebrae). *Ossa vertebrae lumbales* length (OVLL) was measured from the middle point of the body to the 1<sup>st</sup> *processus spinosus* of *sacral* bone. *Ossa vertebrae sacral* length (OVSL) was measured along the *sacral* bone. *Os scapula* length (OSL) was measured from the highest point of body (in the bottom of hump) to *tuber humerus*. *Os humerus* length (OHL) was measured from *tuber humerus* to the middle point of *tuber radius-ulna*. *Ossa radius-ulna* length (ORUL) was measured from *tuber radius-ulna* to

*os carpal*. *Os metacarpale* length (OMCL) was measured from *os carpal* to the end of 1<sup>st</sup> *os phalank*. *Os femoris* length (OFL) was measured from *tuber ilium* to *tuber femoris*. *Ossa tibia-fibulla* length (OTFL) was measured from *tuber femoris* to *tuber calcis*. *Os metatarsale* length (OMTL) was measured from the end of *os tarsus* to 1<sup>st</sup> *os phalanks*. *Coxae* distance (CxD) was measured from left to right of the *tuber coxae*. *Ischium* distance (ID) was measured from left to right of the *tuber ischium*. *Coxae-Ischium* distance (CID) was measured from *tuber coxae* to *tuber ischium*. Body length (BL) was measured from *tuber humerus* to *tuber ischium*. Withers height (WH) was measured from the behind of *os scapula* from dorsal point to the ground. Chest depth (CD) was measured from the behind of *os scapula* from dorsal to ventral points. Hip height (HH) was measured from *os coxae* (*tuber coxae*) to the ground.

### Statistical Analysis

Means, standard deviation, and Pearson's coefficient of correlation in the morphometrics of animals were calculated with SPSS 16.0 software (SPSS Inc, Chicago, USA). From the correlation matrix, data were generated for the principal component factor analysis. Anti-image correlations, Kaiser Meyer Olkin (KMO) measures of sampling adequacy and Bartlett's Test of Sphericity were computed to test the validity of the factor analysis of the data sets [12]. The PCA is a linear combination of the original variables and are estimated in such a way that the first principal component (PC1) explains the largest percentage of the total phenotypic variance [28]. The varimax criterion of the orthogonal rotation method was employed for the rotation of the factor matrix. The choice of varimax rotation is informed by its ability to maximize the sum of the variances of the squared loadings within each column of the loading matrix. This tends to produce some higher loadings and some loadings near zero which is one of the aspects of simple structure that enhance the interpretability of the principal components. Thus, the mathematical model of PCA as follows [29]:

$$Y_{ij} = \sum_{k=1}^q a_{ik} c_{kj} + e_{ij}$$

Where  $Y_{ij}$  is the value of the  $i^{\text{th}}$  observation on the  $j^{\text{th}}$  measure;  $q$  is the number of common factors;  $a_{ik}$  is the value of the  $i^{\text{th}}$  observation on the  $k^{\text{th}}$  common factor (factor loadings);  $c_{kj}$  is the regression coefficient of the  $k^{\text{th}}$  common factor for predicting the  $j^{\text{th}}$  measure and  $e_{ij}$  is the value of the  $i^{\text{th}}$  observation on the  $j^{\text{th}}$  communality value.

## RESULTS AND DISCUSSION

Commonly, the average of buffalo's morphometrics in 3PPI group was higher than 2PPI group as presented in Table 1. However, only two morphometrics of OVLL (backbone area) and ORUL (front locomotion bone area) were significantly different ( $P < 0.05$ ). Hence, all of buffalo's morphometrics in the back locomotion bone area were similar due to in general performance parameter. The Pearson's coefficient of correlation ( $r$ ) value was ranged from -0.21 to 0.89 (2PPI) and -0.26 to 0.97 (3PPI) as presented in Table 2.

In the 2PPI group, very high  $r$  value ( $0.80 < r < 1.00$ ) was reached on WH-HH. Meanwhile high  $r$  value ( $0.60 < r < 0.80$ ) were reached on OHL-OFL (0.74), OHL-OTFL

(0.62) and ORUL-OTFL (0.76). In the 3PPI group very high r value were reached on OFL-OHL (0.80), ORUL-OTFL (0.92) and HH-WH (0.97). Meanwhile, high r value were reached on OMCL-OVCL (0.62), OMTL-OVTL (0.65), BL-OVLL (0.68), OMTL-OSL (0.60), WH-ORUL (0.62), WH-OTFL (0.66), WH-CD (0.70), OTFL-OMCL (0.62), HH-OTFL (0.60), HH-CD (0.69) and CID-CxD (0.66).

**Table 1.** The morphometric characteristics of swamp buffalo bulls morphometrics reared in Indonesia

Morphometric traits (cm)	2PPI (N = 24)	3PPI (N = 20)	Total (N = 44)
<b>Back bones</b>			
<i>Ossa vertebrae cervicales</i> length	31.54±2.21	35.70±2.89	33.43±3.27
<i>Ossa vertebrae thoracicae</i> length	51.75±2.95	57.50±3.35	54.36±4.24
<i>Ossa vertebrae lumbales</i> length*	34.88±2.35	37.85±3.87	36.22±3.44
<i>Ossa vertebrae sacrales</i> length	16.04±1.04	16.50±1.00	16.25±1.04
<b>Front locomotion bones</b>			
<i>Os scapulla</i> length	34.29±2.03	37.80±3.79	35.89±3.42
<i>Os humerus</i> length	26.42±1.64	28.10±1.65	27.18±1.83
<i>Ossa radius ulna</i> length*	35.88±1.48	38.70±2.74	37.16±2.55
<i>Ossa metacarpale</i> length	20.54±0.98	21.80±1.11	21.11±1.20
<b>Back locomotion bones</b>			
<i>Os femoris</i> length	28.96±1.63	30.50±1.24	29.66±1.64
<i>Ossa tibia-fibulla</i> length	39.25±1.92	42.15±2.18	40.57±2.49
<i>Os metatarsale</i> length	23.83±1.09	24.75±0.97	24.25±1.12
<i>Coxae</i> distance	32.75±1.89	35.30±1.95	33.91±2.29
<i>Ischium</i> distance	16.50±1.50	17.30±1.38	16.86±1.49
<i>Coxae-Ischium</i> distance	31.38±2.41	33.05±2.84	32.14±2.72
<b>General performance</b>			
Body length	121.25±5.35	133.20±6.90	126.68±8.52
Withers height	119.33±3.38	124.60±5.15	121.73±4.99
Chest depth	62.54±3.23	68.05±3.10	65.04±4.19
Hip height	122.83±3.36	127.45±5.50	124.93±4.98

\*Means in the same row with different superscripts different significantly (P<0.05); PPI: pairs of permanent incisors

**Table 2.** Pearson's coefficient of correlation (*r*) for swamp buffalo bulls morphometrics at 2PPI (above diagonal) and 3PPI (under diagonal) groups

Morphometric	OVCL	OVTL	OVLL	OVSL	OVVL	OSL	OHL	ORUL	OMCL	OFL	OTFL	OMTL	CxD	ID	CID	BL	WH	CD	HH
OVCL	-	0.44*	0.32	0.16	0.32	0.24	0.67**	0.33	0.40	0.52**	0.46*	-0.03	0.12	0.20	0.28	0.28	0.27	0.48	0.20
OVTL	0.13	-	0.29	0.07	0.29	0.30	0.47*	0.53**	0.35	0.41*	0.49*	0.31	0.05	0.09	0.03	0.39	0.34	0.26	0.29
OVLL	0.25	0.29	-	0.23	0.29	-0.15	0.33	0.37	0.47	0.07	0.39	0.35	0.21	0.14	0.12	0.29	0.16	0.04	0.12
OVSL	0.38	-0.02	0.03	-	0.38	0.38	0.40*	0.34	0.45	0.36	0.19	0.50**	-0.04	0.01	0.12	0.22	0.18	0.33	0.05
OVVL	0.28	0.01	0.52**	-0.14	-	0.34	0.34	0.20	0.11	0.42*	0.34	0.18	-0.17	-0.05	0.50**	0.33	0.16	0.31	0.02
OSL	0.42*	-0.16	0.27	0.16	0.27	-	0.48*	0.58**	0.31	0.74**	0.62**	0.21	0.04	0.07	0.28	0.27	0.20	0.27	0.17
OHL	0.49	-0.23	0.27	0.17	0.27	0.48*	-	0.56**	0.31	0.47*	0.76**	0.34	0.08	0.26	0.05	0.17	0.43*	0.15	0.40*
ORUL	0.62**	0.11	0.37	0.10	0.37	0.34	0.27	0.50**	-	0.26	0.53**	0.33	0.34	0.46*	0.21	0.32	0.31	0.29	0.35
OMCL	0.28	-0.19	0.42*	0.30	0.42*	0.25	0.80**	0.55**	0.27	-	0.41*	0.41*	-0.19	-0.03	0.25	0.21	0.36	0.37	0.36
OFL	0.52**	-0.26	0.34	0.16	0.34	0.59**	0.38	0.92**	0.62**	0.52**	-	0.13	0.29	0.41*	0.43*	0.39	0.48*	0.18	0.51**
OTFL	0.27	0.04	0.65**	0.14	0.65**	0.60**	0.48	0.49*	0.39	0.55**	0.54**	-	-0.21	-0.08	-0.16	0.20	0.19	0.16	0.19
OMTL	0.16	0.02	0.46*	0.14	0.46*	0.30	0.12	-0.12	0.08	0.09	-0.12	0.24	-	0.53**	-0.02	0.67**	0.18	-0.13	0.10
CxD	-0.14	-0.16	0.20	0.31	0.20	0.05	0.31	0.03	-0.06	0.34	0.12	0.38	-0.02	-	0.29	0.09	0.04	0.13	0.17
ID	-0.05	0.21	0.50**	0.08	0.21	0.32	-0.02	-0.13	0.003	0.01	-0.10	0.27	0.66**	0.32	-	0.52**	0.24	0.40*	0.22
CID	0.12	-0.07	0.68**	0.22	0.68**	0.48*	0.42*	0.28	0.19	0.44*	0.28	0.57**	0.41*	0.26	0.57**	-	0.59**	0.77**	0.52**
BL	0.16	-0.08	0.51**	0.26	0.51**	0.54**	0.34	0.62**	0.38	0.59**	0.66**	0.55**	0.01	0.46*	0.28	0.55**	-	0.58**	0.89**
WH	-0.06	0.12	0.26	0.18	0.26	0.36	0.10	0.39	0.22	0.30	0.37	0.50**	0.03	0.21	0.25	0.43*	0.70**	-	0.53**
CD	0.05	-0.06	0.54**	0.12	0.54**	0.57**	0.33	0.57**	0.28	0.57**	0.60**	0.58**	-0.02	0.47*	0.30	0.56**	0.97**	0.69**	-

OVCL: ossa vertebrae cervicales length; OVTL: ossa vertebrae thoracicae length; OVLL: ossa vertebrae lumbales length; OVSL: ossa vertebrae sacrales length; OSL: os scapula length; OHL: os humerus length; ORUL: ossa radius ulna length; OMCL: ossa metacarpale length; OFL: os femoris length; OTFL: ossa tibia-fibula length; OMTL: os metatarsale length; CxD: coxae distance; ID: ischium distance; CID: coxae-ischium distance; BL: body length; WH: withers height; CD: chest depth; HH: hip height. \*(P<0.05); \*\*(P<0.01)

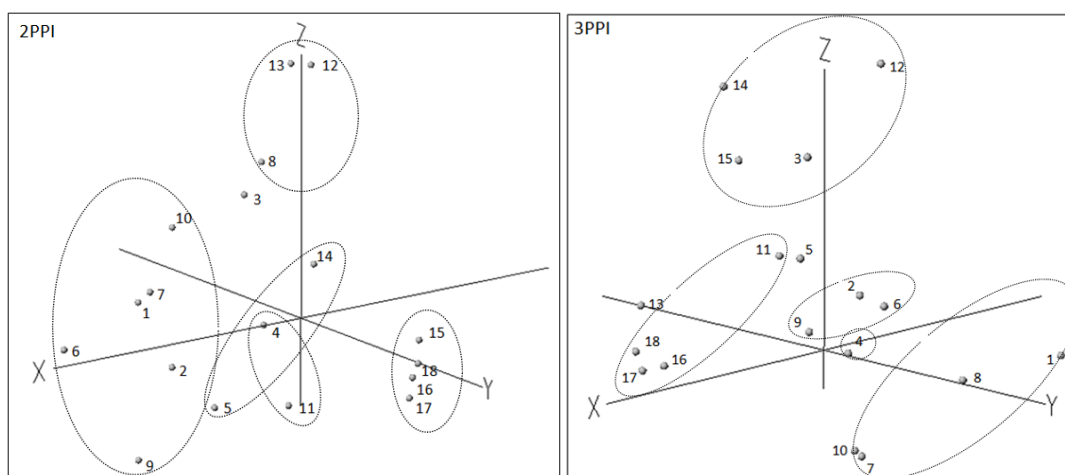
**Table 3.** Rotated component matrix, eigenvalues, total variance, cumulative, communalities, Kaiser-Meijer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity for swamp buffalo bulls morphometrics

Morphometric traits	2PPI (N=24)					3PPI (N=20)						
	PC1	PC2	PC3	PC4	PC5	Com.	PC1	PC2	PC3	PC4	PC5	Com.
<i>Ossa vertebrae cervicales</i> length	0.68*	0.11	0.19	0.33	-0.06	0.62	-0.12	0.88*	0.12	0.04	0.26	0.88
<i>Ossa vertebrae thoracicae</i> length	0.68*	0.28	0.03	-0.07	0.13	0.56	0.01	0.16	0.20	-0.78*	0.17	0.70
<i>Ossa vertebrae lumbales</i> length	0.26	0.07	0.44	-0.13	0.47	0.50	0.38	0.30	0.72*	-0.03	-0.02	0.75
<i>Ossa vertebrae sacrales</i> length	0.13	-0.01	-0.002	0.34	0.80*	0.76	0.09	0.19	0.04	0.02	0.85*	0.76
<i>Os scapula</i> length	0.32	0.003	-0.22	0.70*	0.16	0.67	0.49	0.38	0.44	0.09	-0.44	0.77
<i>Os humerus</i> length	0.85*	-0.03	0.04	0.27	0.18	0.83	0.11	0.36	0.22	0.69*	0.29	0.74
<i>Ossa radius ulna</i> length	0.71*	0.21	0.25	-0.14	0.33	0.74	0.51	0.66*	-0.12	0.37	-0.07	0.85
<i>Ossa metacarpale</i> length	0.30	0.21	0.58*	0.10	0.52	0.75	0.22	0.80*	0.09	-0.07	0.00	0.69
<i>Os femoris</i> length	0.73*	0.18	-0.27	0.25	0.22	0.75	0.38	0.31	0.18	0.63*	0.32	0.77
<i>Ossa tibia-fibulla</i> length	0.68*	0.28	0.46	0.16	0.07	0.79	0.56	0.68*	-0.09	0.33	-0.11	0.90
<i>Os metatarsale</i> length	0.17	0.17	-0.20	-0.14	0.83*	0.81	0.54*	0.34	0.45	0.24	0.04	0.67
<i>Coxae</i> distance	0.001	0.05	0.79*	-0.13	-0.12	0.66	-0.20	0.04	0.86*	0.03	0.01	0.78
<i>Ischium</i> distance	0.06	0.03	0.80*	0.17	-0.03	0.68	0.45	-0.33	0.16	0.31	0.48	0.67
<i>Coxae-Ischium</i> distance	0.10	0.20	0.23	0.81*	-0.11	0.77	0.22	-0.21	0.82*	-0.19	0.08	0.80
Body length	0.08	0.70*	0.11	0.47	0.18	0.77	0.44	0.07	0.68*	0.25	0.09	0.73
Withers height	0.25	0.90*	0.07	0.02	0.07	0.88	0.90*	0.21	0.15	0.17	0.14	0.92
Chest depth	0.10	0.68*	-0.07	0.54	0.15	0.78	0.82*	0.04	0.09	-0.16	0.09	0.72
Hip height	0.23	0.90*	0.11	-0.06	0.01	0.88	0.92*	0.11	0.18	0.19	0.03	0.93
Eigen values	6.09	2.20	2.00	1.61	1.29	-	6.75	2.56	1.91	1.61	1.20	-
Variance (%)	33.83	12.19	11.12	8.94	7.16	-	37.50	14.24	10.60	8.91	6.64	-
Cumulative (%)	33.83	46.02	57.14	66.08	73.24	-	37.50	51.74	62.34	71.26	77.90	-
KMO				0.24								0.24
Bartlett's test				**								**

N: number of animal; PPI: pairs of permanent incisor; PC: principal component; Com.: communality; \*main component; \*\* (P<0.01)

The PCA in buffalo's morphometrics showed that both ages group had five components to explain the body conformation/dimension (Table 3). Thus, all principal components (PC's) were explained the buffalo's morphometrics about 73.24% (2PPI) and 77.90% (3PPI). The first principal component (PC1) in 2PPI group consisted of OVCL, OVTL (backbones), OHL, ORUL (front locomotion bones), OFL and OTFL (back locomotion bones). Meanwhile, PC1 in 3PPI group consisted of OML (back locomotion bone), WH, CD and HH (general performance). The PC1 was explained the buffalo's morphometric about 33.83% (2PPI) and 37.50% (3PPI). Thus total the other PC's were explained the buffalo's morphometric about 39.41% (2PPI) and 40.39% (3PPI).

The communality values in buffalo's morphometrics in both ages group were more than 0.50 (high) and with similar KMO's values (0.24). The eigenvalues in PC1 and PC2 were 6.09 and 6.75 respectively. The component plots of swamp buffalo bulls morphometric characteristics were presented in Figure 2.



**Fig 2.** Component plot in rotated space. 1:Ossa vertebrae cervicalis length; 2:Ossa vertebrae thoracicae length; 3:Ossa vertebrae lumbales length; 4:Ossa vertebrae sacrales length; 5:Os scapula length; 6:Os humerus length; 7:Ossa radius-ulna length; 8:Os metacarpale length; 9:Os femoris length; 10:Ossa tibia-fibulla length; 11:Os metatarsale length; 12:Coxae distance; 13:Ischium distance; 14:Coxae-Ischium distance; 15:Body length; 16:Withers height; 17:Chest depth; 18:Hip height

Nafiu *et al.* [15] reported that the general performance in swamp buffalo bulls (2-3 years age) at Kabaena District of Indonesia were 140.00±18.00 (BL) cm, 119.00±6.00 (WH), and 114±10.00 cm (HH). Meanwhile, the general performance in 4-5 years of age were 144.00±21.00 cm (BL), 129.00±8.00 cm (WH) and 126.00±10.00 cm (HH). The HH of 2PPI's buffaloes in this study was closed to the swamp buffalo bulls (2-3 years age) at Kabaena District. Thus, BL and WH in 3PPI's buffaloes were lower than male swamp buffalo bulls (3-4 years age) at Kabaena District. In addition, Sembiring *et al.* [14] reported that the BL, WH, CD and HH of swamp buffalo bulls (adult age) at Karo Regency of Indonesia were 133.00±8.49 cm; 139.50±4.95 cm; 60.00±1.41 cm and 137.00±4.24 cm respectively. The BL of 3PPI's buffaloes in this study was closed to the

swamp buffalo bulls at Karo Regency. The buffalo's morphometric can be affected by breed (genetic), sex, animal management, and health status.

The  $r$  value between HH and WH in the animals was 0.97 (very high) and similar to swamp buffaloes at Central Java Province of Indonesia i.e. 0.96 as [16]. Meanwhile, the  $r$  value of HH and WH in female Murrah cross buffaloes was 0.65 [30] and lower than the one in this study. Five principal components in this study were explained about 70% of total variance in body morphometrics. Vohra *et al.* [12] obtained four principal components with 13 body morphometrics that explain 70.86% of total variance in female Gojri buffalo's morphometrics. In addition, Vohra *et al.* [13] obtained five principal components with 18 body morphometrics that explain 70.14% of total variance in Chhattisgarhi buffaloes. Johari *et al.* [16] obtained four principal components with a combination of body weight and eight body morphometrics in swamp buffaloes. Therefore, this combination was explained 94% of total variance in buffalo's morphometrics. The PC1 of Chhattisgarhi buffaloes was explained 34.48% of total variance in buffalo's morphometrics with eigenvalue 6.21 and close to the present study. The communality values in all buffalo's morphometrics were more than 0.50 and indicated that the body conformation or body dimension can be explained with these morphometric characteristics.

## CONCLUSION

This research showed that five principal components (PC) of morphometric traits were found in both groups and explained about 70% of total variance in each age groups. Six morphometrics: *ossa vertebrae cervicales* length (OVCL), *ossa vertebrae thoracicae* length (OVTL), *os humerus* length (OHL), *ossa radius ulna* length (ORUL), *os femoris* length (OFL), *ossa tibia-fibulla* length (OTFL) were described as the first component (PC1) for 2PPI animals. Meanwhile, four morphometrics: *os metatarsale* length (OML), withers height (WH), chest depth (CD), hip height (HH) were showed as the PC1 for 2PPI animals. It was concluded that the general performance of WH, CD, HH can be used as morphometric selection criteria for swamp buffalo bulls at 3-4 years age. The PC1 may be used in phenotypic selection as a means to explain body conformation or body dimension of better early maturing buffaloes to be used in breeding programs.

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**Authorship Contributions.** Concept: W.P.B.P., F.H., Design: W.P.B.P., F.H., Data Collection or Processing: F.H., Analysis or Interpretation: W.P.B.P., F.H., Literature Search: W.P.B.P., F.H., Writing: W.P.B.P., F.H.

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