Body morphometric measurements in Murrah crossbred buffaloes (*Bubalus bubalis*)

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**ABSTRACT**

The morphometry study contributes to the comprehension of the animal conformation. The objective of this research was to study the morphometric measurements of crossbred female Murrah buffaloes, aiming to give subsidies to the study of the relations between their body structures and productive or reproductive performances. The morphometric body measurements studied were: the breast width (BW), thigh width (THW), hip width (HW), rump width (RW), rump length (RL), animal depth (AD), body length (BL), front height (FH), hind height (HH), shoulder width (SW), thorax width (TW), loin width (LW), distance from the head to the ischium (DHI) and thoracic perimeter (TP). Descriptive and Pearson correlation analysis were performed. The average values were 43.72 (BW), 51.42 (TW), 39.99 (HIW), 25.38 (RW), 39.78 (RL), 71.72 (AD), 143.07 (BL), 130.05 (FH), 130.80 (HH), 33.00 (SW), 35.25 (CHW), 3.79 (LW), 180.15 (LHI) and 201.30 (TP). The highest correlations were 0.74 for the SW/CHW, 0.69 for the HIW/TW, 0.68 for the TP/RH, 0.66 for the CW/HIW, 0.65 for the HW/RH and 0.64 for the TW/CW. These correlation coefficients between the body morphometric measurements themselves can be used in the selections programmes.

1. Introduction

The buffaloes are originally Asian animals, having as their ancestor, the *Bubalus annee*, Asian wild buffalo. The species presents great adaptive potential and milk production of high nutritional value, with high yield in the production processes of excellent derivatives, especially mozzarella cheese. These traits have allowed advances in breeding buffaloes in the world milk market, providing strong demand for genetically superior animals in milk production systems. However, according to Marcondes (2011), it is necessary to give up the use of tools to assist in the selection and mating processes, allied to good management practices, allowing greater gains in productivity and quality in breeding buffaloes.

The phenotypic characterization of domestic animals consists of describing the exterior traits of each group, differing from other groups, when considered as a whole (Canelón 2005). This characterization included the biometric measurements of each animal’s body structure. The biometric body traits can be studied by using measurements with appropriate instruments, which are called morphometric traits. Morphometric measurement research of animals has as their main objective to study the individual conformation, allowing the racial characterization and classification of the population. In addition, this characterization allows the comparison between and inside genetic groups and establishes the association between the animal’s conformation and function. These traits also contribute to the selection process, in identifying the morphologically superior animals, as well as eliminating the unwanted traits (Carvalho et al. 2010; Lucena et al. 2015).

It is possible to find some body traits about buffaloes in literature (Espinosa-Núnés et al. 2011; Johari et al. 2009; Vohra et al. 2015; Mirza et al. 2015; Dhillod et al. 2017), but studies about the correlation between them are scarce, although they are very important to genetic improvement programmes. As reported by Agudelo-Gómez et al. (2015), the body measurements of female buffaloes and their correlations can aid in predicting the potential and aptitudes of these animals. There is some association between the body measurements, the productive and reproductive traits in buffaloes (Thomas and Chakravarty 2000; Espinosa-Núnés et al. 2011; Kern et al. 2014) and in cattle (Wenceslau et al. 2000; Rennó et al. 2003; Lagrotta et al. 2010; Silva et al. 2011).

The objective of this research was to make a descriptive analysis of body morphometric measurements in Murrah crossbred buffaloes and estimate the correlations between them to provide subsidies to understand the relation between the body structures with the productive and reproductive abilities.

2. Material and methods

2.1. Place of research

The research was carried out at the Agricultural Science Center of the Federal University of Alagoas, located in the city of Rio Lago in the State of Alagoas, Brazil. The research was approved...
by the Ethics Commission on Animal Use of the Federal University of Alagoas (abbreviated as CEUA, UFAL in Portuguese) with the registration N° 05/2017, for the use of live animals during the experiment.

The data of body morphometric traits of the 99 Murrah crossbred buffaloes were used in this study. These buffaloes belonged to the Castanha Grande Farm located in the city of São Luís do Quitunde, Northeast Brazil. The area presents an altitude of approximately ten metres, with the geographic coordinates of 9° 10'06" S and 35° 33'40" W and a rainy tropical climate, according to the Köppen classification.

2.2. Animal management

The buffaloes were milked twice a day (in the morning and afternoon) with a mechanical bucket milker with a piped vacuum line and restrained in tandem with the capacity for 24 individual buffaloes. The buffaloes were bathed before milking, which is important to stimulate intestinal evacuation. This procedure contributed to the maintenance of cleaning the milking room. In addition to contributing to the best milk quality, this practice reduces the stress. During lactation, buffaloes are bred in a semi-intensive system. The buffaloes were kept in a Braquiária humidícula pasture and received all sugarcane plants (Saccharum officinarum), including the aerial part, both enriched with urea in a silage form. In addition, mineral supplementation and balanced ration were provided. The feed was provided in the following proportion: the buffaloes with production between 5 to 7.5 litres of milk/day received 1 kg of ration/day; buffaloes with production between 8 to 10.5 litres of milk/day received 2 kg of ration per day.

2.3. Morphometric traits and methods of recording

The morphometric measurements studied were: the breast width (BW), thigh width (THW), hip width (HW), rump width (RW), rump length (RL), animal depth (AD), body length (BL), front height (FH), hind height (HH), shoulder width (SW), thorax width (TW), loin width (LW), distance from the head to the ischium (DHI) and thoracic perimeter (TP), ear length (EL), ear width (EW), head length (HL), face length (FL) and face width (FW). The measurements were recorded following the methodology applied by Wenceslau et al. (2000), Oliveira et al. (2001) and Carvalho et al. (2010), in which all the body measurements were obtained from female buffaloes before milking. All the measurements were made in centimetres and always done on the left side of the animal to maintain the same standard. A measuring tape and a caliper ruler suitable for animal were used to obtain the measurements.

The measurements were separated into two groups, the first group consisting of the body measurements, and the second group consisting of the head measurements. The traits of the first group were: BW, the width between one side of the breast to the other; THW, the distance between the external angles of the femoral joints; HW, the length from one hip to the other; RW, the distance between the ischia; RL, the distance between the ileum and ischium; AD, the distance between the last thoracic vertebra and the umbilical region (Figure 1); BL, the diagonal of the body between the bottom tip of the scapula until the tip of the ischium; FH, the distance between the withers and the distal extremity of the front member; HH, the distance between the sacral tuberosity and the distal extremity of the back limb; SW, the distance between the scapulas; TW, the distance between the two lateral lines passing through the dorsal angles of the scapula; LW, the distance between the thoracic vertebra and lumbar vertebra; DHI, the distance between the occipital protuberance until the tuberosity of the ischium; and TP, the contour of the thorax passing behind the front limbs and returning perpendicularly by the withers (Figure 2).

The traits of the second group were: EL, the distance between the fixation point of the ears to the cranium until the extremity of the ears; EW, the distance between the two tips in the largest width of the ear; HL, the distance between the occipital until the bottom lip; FL, distance between the nasal cavity and the upper vertex of the orbital arcade; and FW, the distance between the external face of the orbital arcade (Figure 3).

2.4. Statistical analysis

The descriptive analysis and of Pearson correlation were performed, besides the study to identify the possible variation sources to the traits studied. Therefore, preliminary analyzes...
were conducted with the inclusion of the effects of calving order and physiological stage of the female buffaloes. The calving order of the female buffaloes varied from the 1st to 11th order. The physiological stage of the females was divided into four stages: 1st, stage between the conception and 90 days after the conception; 2nd, stage between 90 and 180 days after the conception; 3rd, stage between 180 and 270 days after the conception and 4th, stage between the calving and the conception. The preliminary results showed that these effects were not significant (P > 0.05) and, therefore, were not considered in further analyses.

All the statistical analyses were implemented using algorithms available in *R* 3.4.0 software (R Core Team 2017).

### 3. Results and discussion

The descriptive analysis of the body morphometric measurements of crossbred Murrah buffaloes is presented in Table 1. The variation coefficients (CV) varied from 3.65 to 16.68% (Table 1). The average of the BW was 43.76 cm and this trait is associated to the animal’s breathing ability. According to Ramos (2008), the buffalo BW should be broad reflecting a good respiratory ability. The result of this study showed that the female buffalo breasts were wide.

The THW average was 51.42 cm, being near the average recorded by Vohra et al. (2015), which was 53.6 cm per THW for Gojri female buffaloes. Oliveira et al. (2001) showed higher values in Murrah crossbred buffaloes (59.0 cm), Ahmad et al. (2013) in Nili Ravi buffaloes (56.9 cm), and Rezende et al. (2017) in Murrah female buffaloes (58.9 cm). The rump region is responsible for the movement structure of animals and consists of the rump angles. According to Ramos (2008), the rump should be broad, long and with good muscular. An appropriate formation in this region provides a good angularity of the sacral region, allowing the rump to be slightly inclined and horizontal. In addition, this region is very important for the ability of the female reproduction.

In this study, the HW average was 39.9 cm. In Colombia, Bedoya and Hernández (2013) registered an HW average of 44 cm in Murrah female buffaloes. According to these authors, the HW is strongly related to the ponderal development of buffaloes contributing to higher yielding of noble cuts in the production of beef cattle. In addition, wider hips provide a better female reproductive ability, regarding the fetal development and natural calving. The RW of the female buffaloes was 25.38 cm (Table 1). The average RW value recorded by Bedoya and Hernández (2013) was 24 cm and 27 cm by Vohra et al. (2015). However, a shorter RW (20 cm) was observed by Kocaman et al. (2017) in River buffaloes in Istanbul. Moreover, in Brazil, wider RW values were recorded by Andréa et al. (2010) (49 cm) and Rezende et al. (2017) (32 cm) in Murrah buffaloes. The RW of the female buffaloes in this study may be considered as of average length, which confers a good reproductive capacity to these animals. According to Ramos (2008), the rump area includes the female reproductive organs, especially, the womb. A wider rump width will provide a higher uterine development, while, female buffaloes with a shorter rump are more prone to have difficulties during their calving. However, females with very wide rumps usually are heavy animals, therefore, less efficient and have less longevity. Beyond the reproductive function, the rump is an important structure for the movement of the buffaloes.

The average RL in this study was 39.78 cm, similar to what was observed by Dhillod et al. 2017 in Murrah buffaloes in India. On the other hand, in Pakistan, Ahmad et al. (2013) showed a RL average of 30.20 cm in Nili Ravi buffaloes. The average AD in this study was 71.72 cm, which indicated that the studied buffaloes are deep. According to Ramos (2008), deep animals present a better reproductive and productive performance being more common in breeds that are more appropriate for the meat production. Deep animals are healthy, vigorous, have strong bones and good gestation ability.

The average BL in this study was 143.07 cm (Table 1), while the average BL recorded was 142 cm in Murrah buffaloes (Andréa et al. 2010), 140 cm in Nili Ravi buffaloes (Ahmad et al. 2013), 140 cm in Azikheli buffaloes (Khan et al. 2013) and 146 cm in Nili Ravi buffaloes (Kocaman et al. 2017). However, longer BL averages were reported in Murrah buffaloes by Dhillod et al. 2017 (152 cm) and Mirza et al. 2015 (156 cm).

| Variable | n  | μ   | s  | Min | Max | CV  |
|----------|----|-----|----|-----|-----|-----|
| BW       | 99 | 43.72 | 5.21 | 32.00 | 54.00 | 11.92 |
| THW      | 99 | 51.42 | 5.37 | 40.00 | 63.00 | 10.44 |
| HW       | 99 | 39.99 | 5.62 | 25.00 | 56.00 | 14.04 |
| RW       | 99 | 25.38 | 4.23 | 17.00 | 38.00 | 16.68 |
| RL       | 99 | 39.78 | 4.14 | 32.00 | 56.00 | 10.41 |
| AD       | 96 | 71.72 | 6.06 | 55.00 | 88.00 | 8.45  |
| BL       | 99 | 143.07 | 8.43 | 120.00 | 162.00 | 10.89 |
| FH       | 99 | 130.05 | 5.04 | 116.00 | 148.00 | 3.87  |
| HH       | 95 | 130.80 | 4.78 | 119.70 | 143.00 | 3.65  |
| SW       | 98 | 33.00 | 4.43 | 14.00 | 42.00 | 13.44 |
| TW       | 98 | 35.25 | 4.32 | 25.00 | 44.00 | 12.25 |
| LW       | 99 | 37.79 | 4.79 | 28.00 | 52.00 | 12.69 |
| DHI      | 98 | 180.15 | 19.46 | 19.40 | 204.00 | 10.80 |
| TP       | 98 | 201.30 | 8.10 | 180.00 | 223.00 | 4.02  |

*n*, sample size; μ, average, s, standard deviation; Min, minimum value; Max, maximum value; CV, variation coefficient (%); breast width (BW), thigh width (THW), hip width (HW), rump width (RW), rump length (RL), animal depth (AD), body length (BL), front height (FH), hind height (HH), shoulder width (SW), thorax width (TW), loin width (LW), distance of head until the ischium (DHI) and thoracic perimeter (TP).
In this study, the average FH recorded was 130.05 cm and the average HH was 130.80 cm (Table 1), indicating that the studied buffaloes have medium stature and medium size. In Pakistan, Khan et al. (2013) registered a higher average FH of 131.35 and an average HH of 123.41 cm in Azikheli buffaloes. In India, Vohra et al. (2015) registered an average FH of 128.66 cm in Gojri buffaloes. In Brazil, Andréa et al. (2010) and Rezende et al. (2017) both registered an average FH of 139 and 133 cm, respectively, in Murrah buffaloes. In Colombia, Bedoya and Hernández (2013) registered an average FH of 134.50 and an average HH of 137.89 cm in Murrah buffaloes. In Pakistan, Dhillod et al. (2017) registered an average FH of 135 cm in Murrah buffaloes. In Istanbul, Kocaman et al. (2017) also registered a higher average FH of 137.10 and an average HH of 132.50 cm in River buffaloes. In Colombia, Bedoya and Hernández (2013) registered an average HH of 134.50 and an average HH of 137.89 cm in Murrah buffaloes. In Pakistan, Dhillod et al. (2017) registered an average FH of 135 cm in Murrah buffaloes. In India, Vohra et al. (2015) reported an average FH of 128.66 cm in Gojri buffaloes. In Brazil, Andréa et al. (2010) and Rezende et al. (2017) both registered an average FH of 139 and 133 cm, respectively, in Murrah buffaloes. In Colombia, Bedoya and Hernández (2013) registered an average FH of 134.50 and an average HH of 137.89 cm in Murrah buffaloes. In Pakistan, Dhillod et al. (2017) registered an average FH of 135 cm in Murrah buffaloes. In Istanbul, Kocaman et al. (2017) also registered a higher average FH of 137.10 and an average HH of 132.50 cm in River buffaloes compared to the current study.

The average SW was 33.00 cm and the average LW was 37.79 cm in this study. The SW and TW are important parts due to their association with the respiratory and digestive systems, and metabolic functions of the animals. Ramos (2008) emphasized that the SW and TW should be wide and long, mainly in the front, providing a good respiratory and digestive ability. The LW should be wide and harmoniously attached to the chest. The loin needs to be strong, with lumbar vertebrae well defined and harmoniously attached to the rump.

The average DHI studied was 180.15 (Table 1), indicating that the buffaloes had long diagonal lines, therefore considered long animals. The average TP was 201.30 cm (Table 1), while a lower TP average (187 cm) was reported by Oliveira et al. (2001), also in Murrah crossbred buffaloes. According to Ramos (2008), a wide thoracic perimeter provides a good digestive ability. The digestive and respiratory systems are in the thorax area, therefore it needs to be wide and rounded.

The average head traits of the female buffaloes in this study are presented in Table 2. The average EL was 21.87 and the average EW was 12.12 cm. A similar EL average value of 21.39 cm was recorded by Khan et al. (2013) in Azikheli buffaloes, while as in the present study, a lower EW average value of 12.12 cm was reported. Javed et al. (2013) recorded a higher EL average of 29.50 cm in Nili Ravi buffaloes and Vohra et al. (2015) recorded an EL average of 28.76 cm in Gojri buffaloes.

In the present study, the average HL was 51.36 cm. Similarly, Khan et al. (2013) reported an average HL of 52.45 in Azikheli buffaloes and Vohra et al. (2015) reported an average value of 48.58 cm in Gojri buffaloes. Ramos (2008) emphasized that the structure, size and appearance of the ear are important in the description of the racial buffalo standard. Generally, the desirable head size standard is from small to moderate. The FL and FW average value was 37.38 and 19.74 cm respectively. Earlier Khan et al. (2013) reported FL and FW average values of 52.45 cm and 22.33 cm in Azikheli buffaloes, respectively. While Vohra et al. (2015) reported a FW average value of 30.22 cm in Gojri buffaloes.

The correlation between the body morphometric measurements varied from −0.04 to 0.74 (Table 3) and just 10% were significant (P < 0.01). The highest correlations were SW/TW (0.74), THW/HW (0.69), HH/TP (0.68), HW/RW (0.66), FW/RW (0.64), Figure 4 (Supplementary material).

The phenotypic correlation of body measurements of Murrah crossbred buffaloes is presented in Table 3. The correlation between the SW/TW (0.74) indicates that the wider buffalo shoulder width implies a larger thorax width, giving them a good respiratory ability, and contributing them to have a good metabolic performance. The correlation between the THW and HW values was 0.69 (Table 3), showing the close relation between these measurements, being therefore expected, because the HW value (distance between the hips) contained the THW (distance between the external angles of the thigh joints). The choosing of the females was based on one of them (THW or HW) would bring benefits to the other one as well. The relation between the HH/TP was 0.68 suggesting that the bigger the HH value, the bigger the thoracic perimeter of the females will be.

There was also a moderate correlation between the HW/RW (0.66, Table 3), showing that these traits are associated and there

| Variable | n | µ | s | Min | Max | CV |
|----------|---|---|---|-----|-----|----|
| EL       | 99 | 21.87 | 2.11 | 11.00 | 30.00 | 9.66 |
| EW       | 99 | 12.12 | 0.97 | 9.00 | 15.00 | 8.02 |
| HL       | 99 | 51.36 | 5.71 | 40.00 | 97.00 | 11.12 |
| FL       | 99 | 37.38 | 3.75 | 24.00 | 45.00 | 10.03 |
| FW       | 99 | 19.74 | 1.59 | 14.00 | 24.00 | 8.08 |

n, sample size; µ, mean; s, standard deviation; Min, minimum value; Max, maximum value; CV, coefficient of variation (%); EL, ear length; EW, ear width; FL, face length; FW, face width.

Table 3. Phenotypic correlation of body measurements of Murrah crossbred buffaloes.

| BW | SW | TW | LW | THW | HW | RW | RL | AD | BL | DHI | FH | HH | TP |
|----|----|----|----|-----|----|----|----|----|----|-----|----|----|----|
| 1.00 | 0.03 | -0.23 | -0.40** | -0.33 | -0.09 | -0.28 | -0.09 | -0.37** | 0.01 | 0.12 | -0.01 | 0.19 | 0.31 |
| SW | 1.00 | 0.74** | 0.27 | 0.24 | 0.30 | 0.17 | -0.04 | 0.05 | 0.13 | 0.06 | 0.20 | 0.34 | 0.49** |
| TW | 1.00 | 0.53** | 0.52** | 0.48** | 0.32 | 0.02 | 0.20 | 0.21 | 0.02 | 0.21 | 0.23 | 0.29 |
| LW | 1.00 | 0.49** | 0.46** | 0.45** | 0.30 | 0.47** | 0.13 | -0.01 | 0.22 | 0.12 | 0.15 |
| THW | 1.00 | 0.69** | 0.64** | 0.64** | 0.11 | 0.49** | 0.47 | 0.21 | 0.38 | 0.15 | 0.15 |
| HW | 1.00 | 0.66** | 0.25 | 0.19 | 0.25 | 0.21 | 0.29 | 0.09 | 0.20 |
| RW | 1.00 | 0.13 | 0.32** | 0.08 | 0.08 | 0.30 | 0.01 | 0.15 |
| RL | 1.00 | 0.49** | 0.24 | 0.13 | 0.20 | 0.09 | 0.16 |
| AD | 1.00 | 0.44 | 0.25 | 0.33 | 0.15 | 0.08 |
| BL | 1.00 | 0.35* | 0.37* | 0.28 | 0.24 |
| DHI | 1.00 | 0.07 | 0.03 | 0.14 |
| FW | 1.00 | 0.65** | 0.49** |
| HH | 1.00 | 0.68** |
| TP | 1.00 |

**Significant the 1% (P < 0.01); *Significant the 5% (P < 0.05); breast width (BW), shoulder width (SW), thorax width (TW), loin width (LW), thigh width (THW), hip width (HW), rump width (RW), rump length (RL), animal length (AD), body length (BL), distance of head until the ischium (DHI), front height (FH), hind height (HH) and thoracic perimeter (TP).
Table 4. Phenotypic correlation of head morphometric characteristics of Murrah crossbred buffaloes.

|     | EL   | EW   | HL   | FL   | FW   |
|-----|------|------|------|------|------|
| EL  | 1.00 | 0.40**| 0.14 | 0.12 | −0.04|
| EW  | 1.00 | −0.07| 0.04 | 0.07 | −0.07|
| HL  | 1.00 | 0.40**| 0.07 | 0.07 | −0.20|
| FL  | 1.00 | −0.20| 0.07 | 0.07 | 1.00 |

**Significant the % (P < 0.01); *Significant the % (P < 0.05); ear length (EL), ear width (EW), head length (HL), face length (FL) and face width (FW).

is a harmony in the buffalo bodies studied. The correlation between FH/HW (0.65, Table 3) also was moderate, reflecting a linearity of the buffalo bodies. The correlation between the BL/FH was 0.37 (P < 0.05), and between the RW/RL was 0.13 (P > 0.05). These results were different from those obtained earlier by Kocaman et al. (2017), which were 0.66 for BL/FH, and 0.89 for RW/RL.

In the present study, the correlation between the THW/RW was 0.64, and between the THW/BL was 0.47 (Table 3). These values were distinct from the THW/RW (0.91) and THW/BL (0.57) correlations reported earlier by Andréa et al. (2010) in Murrah buffaloes. However, the correlation between the THW/BL estimated in the present study (0.47) was near to the THW/BL correlation (0.44) reported earlier by Dhillod et al. (2017).

The phenotypic correlation of head morphometric characteristics of Murrah crossbred buffaloes is presented in Table 4. The relation between the morphometric measurements of the buffalo heads may help in describing and standardizing different buffalo breeds. The results showed that just two correlations were significant, EL/EW and HL/FL (0.40, P < 0.01), which presented similar values between themselves (Table 4). These results suggest that there is no strong relation between the EL/HL and EW/FL. The correlations between the EL/FL was 0.12 (P > 0.05), and between the EL/FW was −0.04 ([P > 0.05] Table 4). These results were different from those obtained by Vohra et al. (2015) in Gojri buffaloes, whose EL/FL correlation was 0.33 and RL/FW correlation was 0.17.

4. Conclusions

The female buffaloes in this study showed long and wide breasts, medium to long rumps, medium heights, deep animals, and long diagonal lines, being therefore considered large animals with good reproductive and productive abilities.

The correlations between the morphometric measurements of female buffaloes showed that the bigger the shoulder width, the greater the thorax width will be, the bigger the thigh width, the larger the rump width will be, and the bigger the body length, the higher the wither height will be. These correlation coefficients between the body morphometric measurements themselves can be useful in the selections programmes. Moreover, other studies should be done with the objective to expand the knowledge of the relation between the body measurements and the reproductive and productive performance of buffalo species.

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Disclosure statement

The authors declare that they have no conflict of interest.

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