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# Sexual Dimorphism of the Pelvic Bone and Limbs of *Francolinus bicalcaratus*

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**ABSTRACT**

***Introduction***: The Double-spurred francolin (*Francolinus bicalcaratus*) also known as African Bush Fowl, is a popular bird found in all the geological zones of West Africa. The bird is closely related to galliformes like jungle fowls and cortunix feeding on insects, seeds and vegetable matter. We investigated the pelvic and long bones in *Francolinus bicalcaratus* to determine the differetianting features as well as the depth of sexual dimorphism in these bones.
***Methods***: Skeleton from five males and five females *Francolinus bicalcaratus* were acquired using standard evisceration methods. Linear parameters were measured using a Digital Vernier Caliper (Neiko® China, sensitivity of 0.01mm,). A Protractor was used to determine the angles. All morphometric data obtained were subjected to one-way analysis of Variance (ANOVA) at a $p < 0.05$.
**Results**: The two foramina in the male pelvic bone had higher mean values compared to the female, but the acetabulum was non-significantly wider in the female The adult male birds bore two tibio-tarsal spurs. The first (closer to the distal end of the bone) was longer than the second. The mean values of pelvic bone parameters were wider in female than male except for the pelvic length, and pubic bone length. The femur, tibiotarsal and tarso-metatarsal length of male was not significantly wider relative to female. The male had longer femur but the female epiphyseal ends of the bone were wider in mean values. The male also had a significantly higher greater trochanter compared to the female. The tarsometatarsal bone that bore the spurs in male was also longer than in female. In the female, the epiphyseal end is wider but with no significant variant ($p>0.05$) compared to the male epiphyseal end.
***Significance:*** The observations made in the course of this study will provide baseline data and other foundational information relevant to the conservation of this animal.

## Introduction

Francolins belong to the Pternistis ("Spurfowl") group of the most common pheasants in Africa, the family, Phasianidae (Mentis and Bigalke, 1980). They are terrestrial birds that share a close relationship with galliformes like jungle fowls and cortunix. They feed on insects, seeds and vegetable matter. Most of the species in this group present spurs on their tarsi (Hall, 1963). The Double-spurred francolin (*Francolinus bicalcaratus*), commonly called African Bush Fowl, "Aparo" in the Southwestern Nigeria is one of the popular, successful birds in all the geological zones of West Africa (Oluwayelu *et al.*, 2014; Aro and Akinmoladun, 2015).
At present, though it appears to be available despite environmental, climatic changes and human exploitation. It is a major source of wildlife meat and eggs, contributing significantly to the total game meat production in Nigeria (Mbinkar *et al*., 2005). In this regard, studies have shown it to be declining in population (del Hoyo *et al*., 1994; Hanane and Qninba, 2014). Several studies of different anatomic areas of Francolin species have been studied (Purwar, 1975; Khaliq *et al*., 2011). In recent times, study on the osteology of many different species of both terrestrial and flying birds have been carried out in correlations to their locomotion, survival and wide distributions (Ekeolu *et al*., 2016). The talons and hollow skeleton of some birds and eagles have been implicated in their survival (Lee, 2014). There is no report on the osteology of *Francolinus bicalcaratus* much less the sexual dimorphism of its bones. Hence there is a need to investigate the osteo-morphology and the sexual dimorphism of the bones of this bird.

## Materials and methods

*Animals*
A total of ten (five males and five female) *Francolinus bicalcaratus* birds were part of the animals used for an ongoing research on several visceral organs of the species. They were acquired in a local market for wildlife at Sasa, Ibadan, Nigeria.

*Necropsy Sedation and organ Excision.*
The birds were deeply sedated by intramuscular Ketamine

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They were euthanised by introduction of air into the jugular vein. They were dipped in clean water to prevent contamination of the air and environment through dust. The birds were then macerated and carefully teased out using scalpel blade followed by removal of extraneous tissues with picking tools. The skeletal framework with remaining soft tissue strands were then boiled in NaOH and detergents. They were soaked in Hydrogen Peroxide and Hypochlorite solution over-night, washed and dried. All the linear parameters were measured using a Digital Vernier Caliper (Neiko® China, sensitivity of 0.01mm,). A Protractor was used to determine the angles.

*Statistical analysis*
All morphometric data obtained were subjected to one-way analysis of Variance (ANOVA) at a P-value <0.05 using the Graph Pad Prism 4 software.

## RESULTS

*Gross Observations: The pelvis*
The male (**A**) *Francolinus bicalcaratus*, showing its double spur, (**PS**), the proximal spur; (**DS**) the distal spur and the digits (**DG**) in (**B**) is shown in Figure 1. The pelvis (Figure 2) was incomplete without pelvic symphysis but with thin rod of pubic bone that extended caudo-dorsally on the ventral border of the ischium, beyond it by 4mm. The ischium (Figure 3) was oriented vertically as it ran caudo-ventrally beyond the three free coccygeal bones, just abutting the ischial tuberosity. It extended cranially and fused with the synsacrum to form a plateau, and the pygostyle. The ilio-ischiactic foramen was bigger and caudal to the acetabulum but dorsal to the small obturator foramen. The acetabulum bore no notch but a dorsal articular facet, the anti-trochanter and a process that extended cranio-ventral at angle 60˚. The ischium extended way beyond the ischiatic tuber and the caudal vertebrae. The transverse processes of the sacral bones were synostotic with the wings of the ilium. The body of all the sacral vertebrae were fused. The dorsal sacral crest is fused with the proximal one-third of the iliac crest with a thin sheet of bone.

*Metric Observation*
The average length of the male pelvic bone was 68.59 ± 0.72 mm and the female pelvic bone was 66.35 ± 1.88 mm. There was no significant difference when compared at $P < 0.05$. The observation was also similar for all the parameters measured. The male *F. bicalcaratus* was observed to have larger dimensions for many of the parameters measured except for the bicristal diameter for male 24.30 ± 0.50 mm and female 25.50 ± 2.14 mm. The average diameter for pelvic inlet in the male was 19.30 ± 0.45 mm and 22.22 ± 1.71 mm in the female. The pelvic outlet average diameter in the male was 20.14 ± 1.51 mm and 24.28 ± 1.27 mm in the female. The synsacrum length were 11.26 ± 0.34 mm and 13.97 ± 2.11 mm, in male and female respectively. There was no significant metric sexual difference at $P < 0.05$. The mean diameter between the ischial tuberosity in the male was 12.69 ± 0.94 mm while in the female the mean diameter was 15.27 ± 1.63 mm. The comparison of the male mean diameters between the ischial tuberosity and that of the female projected non-significant sexual variation at $P < 0.05$. Table 1 shows the pelvic bone parameters measured and the mean values for both the male and female *F. bicalcaratus.*

*Non-metric observations: The Femur*
The femur was a long bone, somewhat curved outwards from the femoral head and then inward at the proximal half. The greater trochanter extended the whole length of the epiphysis to continue with the lateral border of the shaft. The lesser trochanter was on the medial surface but lateral to the head of the femur. The distal epiphysis bore foramina that were dorsal to the trochlea (articular surface).

*Metric Observation*
Table 2 shows the femoral parameters measured and the mean values for both the male and female *F. bicalcaratus.* The average length of the femur in the female was 66.00 ± 0.14 mm while that of male was 65.00 ± 0.1 mm. The femur was proportional in length with the pelvic bone with a ratio of 1:1, however the female had a longer femur than the male but the variation was not significant at $P < 0.05$. When the length of the head of femur with mean values of 5.25 ± 0.50 mm in the male and 4.29 ± 0.18 mm in the female were compared there was no significant variation at $P < 0.05$. This was so for other parameters too except for the diameter of the diaphysis with sexual variations and mean values of 6.83 ± 0.60 mm and 4.43 ± 0.20 mm. At the same p value, there was a significant variation in the mean measurement of the distance between the medial border of the femoral head and the greater trochanter. The trochanteric diameter was observed to vary significantly at $P < 0.01$ with mean values of 7.44 ± 0.63 mm and 4.71 ± 0.42 mm for male and female, respectively. This variation was also seen with the length of the groove on the lateral aspect of distal epiphysis of the femur.

*Gross observations: The Tibiotarsal and Fibula*
The tibiotarsal and the fibula were relatively long straight bones compared to the femur. The fibula was a separate bone that extended from the lateral condyle of the tibiotarsal to just the lateral malleoli. The tibiotarsal bore a medial condylar eminence.

*Metric observations*
Table 3 shows the tibio-tarsal parameters measured and the mean values for both the male and female *F. bicalcaratus.* The femur and tibio-tarsal length ratio were 3:4 for both sexes. There was no significant difference between male and female tibio-tarsal length with mean values of 84.75 ± 0.88 and 82.71 ± 2.06 mm, respectively. There was no significant difference between the length of the fibula in the male and female *F. bicalcaratus* with a mean value of 57.00 ± 1.68 mm and 52.80 ± 4.50 mm, respectively. The parameters measured in both male and female showed no significant variation.

*Gross observations: Tarso-metatarsal*

Table 4 shows the metatarsal parameters measured and the mean values for both the male and female *F. bicalcaratus*. The tarso-metatarsal bone is somewhat flattened dorsoventrally. It bore the spur. This was dimorphic to *Francolinus bicalcaratus* as it was double in the male and single in the female bird.

*Metric observations*

The length of the spur was twice as long in the female compared to the male with an average length of 0.96mm and 0.54mm respectively with an average inter-spur distance of 17.3mm on the left and 16.3mm on the right tarso-metatarsal bone. Between the male and female *F. bicalcaratus*, the only variable that showed significant variation for all the parameters measured was the length of tarso-metatarsal bone with mean values of 58.25 ± 0.53 mm and 53.33 ± 1.26 mm in the male and female respectively. The mean mid-regional thickness of the tarso-metatarsal bone in the female birds were significantly lower than that of the male at $p< 0.001$. The proximal and distal aspects of all the long bones in the female were wider than that of the male but this observation was not significant.

**Table 1**: Shows the pelvic bone parameters measured and the mean values for both the male and female *F. bicalcaratus*

| PARAMETERS | MEAN ± SEM (MALE mm) | MEAN ± SEM (FEMALE mm) |
|---|---|---|
| **WLP** | 68.59 ± 0.72 | 66.35 ± 1.88 |
| **LIB** | 32.49 ± 0.38 | 32.09 ± 0.82 |
| **LPB** | 34.34 ± 0.63 | 32.59 ± 1.28 |
| **LIS** | 25.69 ± 0.70 | 24.45 ± 0.88 |
| **AT** | 4.93 ± 0.11 | 5.09 ± 0.12 |
| **ISF** | 9.309 ± 0.37 | 9.25 ± 0.43 |
| **OF** | 5.003 ± 0.36 | 4.75 ± 0.13 |
| **BSC** | 24.30 ± 0.50 | 25.50 ± 2.14 |
| **PI** | 19.30 ± 0.45 | 22.22 ± 1.71 |
| **PO** | 20.14 ± 1.51 | 24.28 ± 1.27 |
| **AP** | 12.69 ± 0.94 | 15.27 ± 1.63 |
| **ISD** | 26.84 ± 0.48 | 28.07 ± 1.09 |
| **LSA** | 30.19 ± 0.46 | 29.63 ± 0.63 |
| **OA** | 11.26 ± 0.34 | 13.97 ± 2.11 |
| **LS** | 8.113 ± 0.24 | 7.417 ± 0.29 |
| **PBS** | 11.46 ± 0.39 | 9.716 ± 0.90 |

Key: WLP: Length of the pelvic bone; LIB: Length of ilium; LPB: Length of pubic bone; LIS: Length of ischium; AT: diameter of acetabulum; ISF: diameter of ilio-ischial foramen; OF: diameter of obturaor foramen; BSC: Bicristal diameter; PI: Pelvic inlet diameter; PO: Pelvic outlet diameter; AP: Length of the acetabular process; ISD: Diameter between the ischial tuberosity; LSA: Distance between sacrum and the cranial aspect of acetabulum; OA: Distance between dorsal articular facets; LS: Length of synsacrum

**Table 2**: Shows the femoral parameters measured and the mean values for both the male and female *F. bicalcaratus*

| PARAMETERS | MEAN±SEM (MALE) mm | MEAN±SEM (FEMALE) mm |
|---|---|---|
| **LF** | 66.00 ± 0.14 | 65.00 ± 0.17 |
| **DH** | 5.25 ± 0.46 | 4.29 ± 0.18 |
| **DD** | 9.56 ± 0.34 | 10.43 ± 0.43 |
| **DP** | 9.67 ± 0.33 | 10.29 ± 0.29 |
| **DDP** | 6.83 ± 0.52 | 4.43 ± 0.20 |
| **DT** | 7.44± 0.63 | 4.71 ± 0.42 |
| **DLG** | 3.38 ± 0.32 | 2.43 ± 0.20 |
| **HP** | 5.73 ± 0.27 | 4.00± 0.218 |

Key: LF: Length of femur measured between the highest and lowest points on the epiphysis; DH: Diameter of head of femur; DD: Diameter of distal epiphysis; DP: Diameter of proximal epiphysis; DDP: Diameter of diaphysis; DT: Distance between the trochanters; DLG: Length of the groove on the lateral aspect of the distal epiphysis; HP: Distance between the medial aspect of femoral head and the greater trochanter.

**Table 3:** Shows the tibio-tarsal parameters measured and the mean values for both the male and female *F. bicalcaratus*

| PARAMETERS | MEAN±SEM (MALE) mm | MEAN± SEM (FEMALE) mm |
|---|---|---|
| **LWT** | 84.75 ± 0.88 | 82.71 ± 2.06 |
| **LWF** | 57.00 ± 1.680 | 52.80 ± 4.50 |
| **DT** | 14.00 ± 0.19 | 14.71 ± 0.29 |
| **DF** | 6.25 ± 0.16 | 6.40 ± 0.25 |
| **DTr** | 8.50 ± 0.27 | 8.71 ± 0.18 |
| **DShF** | 5.29 ± 0.18 | 5.25 ± 0.16 |
| **HTh** | 12.25 ± 0.25 | 13.29 ± 0.97 |
| **DDF** | 3.25 ± 0.16 | 3.43 ± 0.20 |

Key: LWT: Length of tibia measured between the highest and lowest points on the bone; LWF: Length of fibula measured between the highest and lowest points on the bone; DT: Diameter of the tibia head; DF: Diameter of fibula head; DTr: Diameter of the distal part of tibiotaesal bone; DShF: Diameter of bone measured at the mid-shaft; HTh: Height of tibiotarsal head; DDF: Diameter of foramen on the distal aspect of the bone.

**Table 4**: Shows the metatarsal parameters measured and the mean values for both the male and female *F. bicalcaratus*

| PARAMETERS | MEAN±SEM (MALE) mm | MEAN±SEM (FEMALE) mm |
|---|---|---|
| **LW** | 58.25 ± 0.53 | 53.33 ± 1.27 |
| **DD** | 5.50 ± 0.42 | 5.83 ± 0.48 |
| **DPT** | 10.50 ± 0.34 | 11.50 ± 0.38 |
| **DDT** | 7.88 ± 0.99 | 9.33 ± 0.21 |
| **PARAMETERS** | **MEAN±SEM (MALE) mm LS1** | **MEAN±SEM (FEMALE) mm LS2** |
| **LS** | 6.25 ± 1.45 | 4.75 ± 1.18 |
| **DSS** | 31.50 ± 0.80 | 16.25 ± 1.70 |

**Key:** LW: Length of metatarsal bone; DD: Diameter of metatarsal bone at the thinnest points; DPT: Diameter at the proximal aspect of the bone; DDT: Diameter of distal region of the bone; LS: Length of spur; DSS: Distance between the two spurs; DH: Distance between proximal aspect of bone and second spur; DP: Distance between distal aspect of the bone and the first spur.

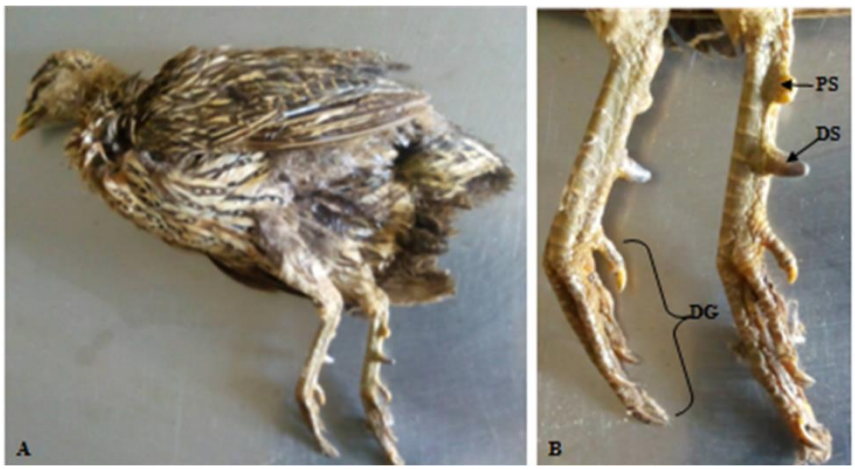


**Figure 1.** The male (**A**) *Francolinus bicalcaratus* showing its double spur, (**PS**), the proximal spur; (**DS**) the distal spur and the digits (**DG**) in (**B**).


**Figure 2:** Photograph of the femur, tibia and fibula, and the metatarsal of *Francolinus bicalcaratus* showing the whole length (**LF**), (**LH**), and (**LW**) of each bone in (**A**), (**B**), and (**C**)

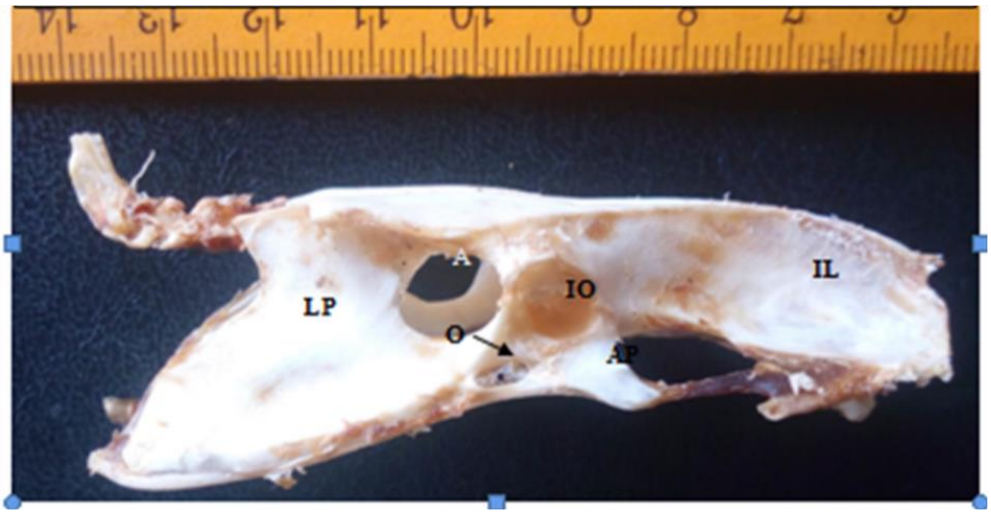


**Figure 3**: Photograph of the right lateral view of the pelvic bone of *Francolinus bicalcaratus* showing the whole length of the pelvic bone (**WLP**), the acetabular process length (**AP**), the obturator foramen **(O),** ischium (**LP**), Acetabulum (**A**), acetabular process (**AP**), ilio-ischial foramen (**IO**), ilium (**IL**) and ischial tuberosity (**IT**).

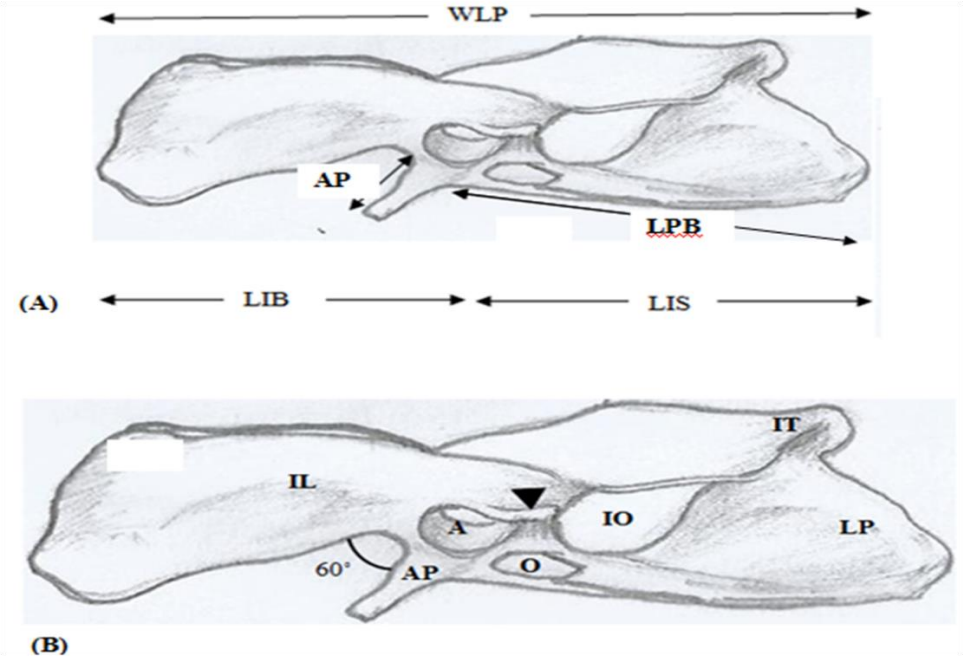


**Figure 4:** Illustration of the right lateral view of the pelvic bone of *Francolinus bicalcaratus* showing **(A)** some of the parameters measured: the whole length of the pelvic bone (**WLP**), the acetabular process length (**AP**), Length of pubic (LPB), ilium (**LIB**) and ischial (**LIS**) bones; **(B)**angle between the acetabular process and the ilium (**60º**), the obturator foramen **(O),** ischium (**LP**), Acetabulum (**A**), acetabular process (**AP**), ilio-ischial foramen (**IO**), ilium (**IL**) and ischial tuberosity (**IT**). The black arrow head points to the articular facet, just dorsal to the obturator foramen and caudal to the acetabulum.

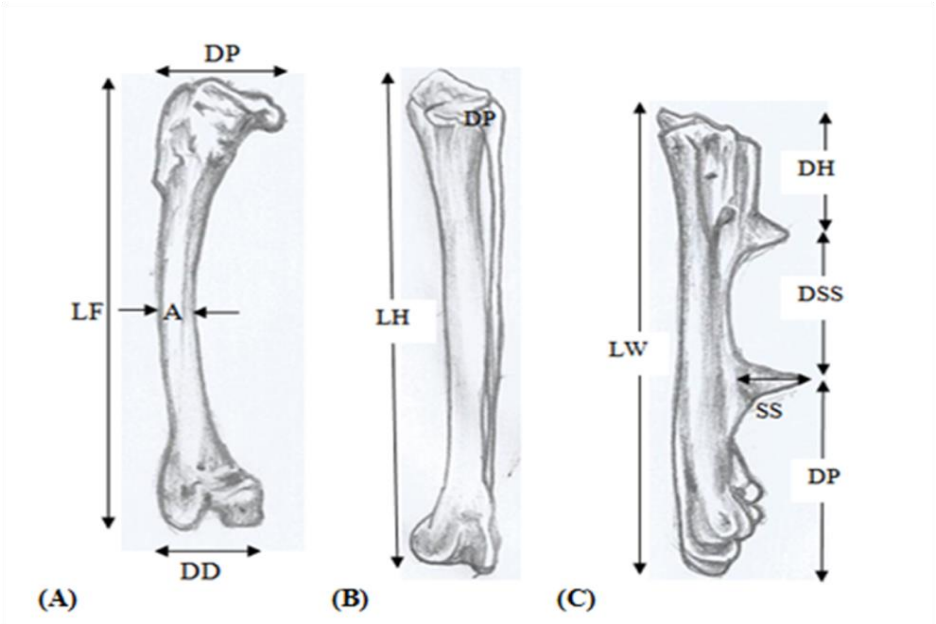


**Figure 5:** Illustration of the long bones of *Francolinus bicalcaratus* showing **(A)**the left femur and some of the parameters measured: the whole length of the bone (**LF**), the proximal epiphysis diameter (**DP**), diaphysis diameter (**A**), distal epiphysis diameter (**DD**); **(B)** the tibotarasal bone, showing: the length of the bone (**LH**), the point of tibiotarsal with fibular (**DP**); **(C)**male metatarsal bone showing: the whole length (**LW**), the length of the spur (**SS**), distance between the first spur and the distal part of the bone (**DP**) distance between the second spur and the proximal part of the bone (**DH**) distance between the two spurs (**DSS**).

## Discussion

*Francolinus bicalcaratus*, a burst flier, flies quite powerfully over short distances as an escape mechanism (Michael *et al*., 2012). The pelvic bone of birds is typically with an open pubis and two foramina: the ilio-ischiatic and the obturator foramina (King and McLelland, 1975). Even though there are no significant difference between the pelvic bone length of the male and female; however, that of the male has higher mean values which corresponds to the findings of Charuta et al. (2007) on Ostrich pelvic bone sexual dimorphism. The position and orientation of acetabulum and other bones of the pelvis has a correlation with the stance in vertebrate animals (Elaine *et al*., 2014). The obturator foramen in both sexes of *F. bicalcaratus* has similar oval shape. This is also noticed for the ilio-ischial foramen with a larger roughly oval shape. The acetabulum bears a long acetabular process. This is unique to the pelvic bone of *F. bicalcaratus*. This may aid the stance and locomotory capability as it may present a platform for a special muscle.

This size of the acetabular process is not significantly different in both sexes. Although *F. bicalcaratus* is a small bird, the femoral length is relatively smaller to the length of tibiotarsal and almost equal in length to the tarso-metatarsal, as it has been observed comparing the pelvic limb length of smaller birds with that of larger species (Bohmer *et al.*, 2019). The tibio-tarsal bone has the highest value for length of all the pelvic limbs, similar to the morphometric study on ostrich (Charuta *et al.*, 2013) but unlike in large bird (Charuta *et al*., 2007), the tarso-metatarsal bone is no longer than the femur. The male *Francolinus bicalcaratus*, as it has been documented generally for avian species (Dye *et al*., 1987) has a shorter femur than the tibio-tarsal. The male tarso-metatarsal is longer than the female but the proximal and distal ends with the diaphysis is wider averagely in female than in male, similar to the observation in *Sphecius speciosus* (Joseph *et al*., 2008), except that even in the Cicada killer, the tarso-metatarsal length was longer. The first spur is not significantly longer than the second in the male, both has straight and horizontal orientation. The acetabulum in this bird has a perforated centre as it is seen in most avian species.

## CONCLUSION

The study showed that parameters measured for the pelvic bone and pelvic limbs indicated significant sexual dimorphism for the *Francolinus bicalcaratus* few gross features and considerable measureable parameters. Some were not significant, even though there were differences in the mean values. The work will therefore be a template for further studies on *F. bicalcaratus* in this regard.

## COMPETING INTEREST

The authors declare that there is no competing interest.

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