BIODIVERSITAS
Volume 25, Number 8, August 2024
Pages: 2740-2748

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250847

Sex determination in Japanese quails (*Coturnix japonica*) based on head morphometry variation among age

DEVIA YOANITA KURNIAWATI[1], YULIANNA PUSPITASARI[2], ADITYA YUDHANA[1], AMUNG LOGAM SAPUTRO[1], YENI DHAMAYANTI[2], AGUS PURNOMO[3], MUHAMMET BAYRAM[4], MUHAMMAD THOHAWI ELZIYAD PURNAMA[1,4,♥]

[1]Division of Veterinary Medicine, Department of Health and Life Sciences, Faculty of Health, Medicine, and Life Sciences, Universitas Airlangga. Jl. Wijaya Kusuma No.113, Banyuwangi 68425, East Java, Indonesia. Tel.: +62-856-3673726, ♥email: thohawi@fkh.unair.ac.id
[2]Department of Veterinary Science, Faculty of Veterinary Medicine, Universitas Airlangga. Jl. Dr. Ir. H. Soekarno, Surabaya 60115, East Java, Indonesia
[3]Department of Veterinary Surgery and Radiology, Faculty of Veterinary Medicine, Universitas Gadjah Mada. Jl. Fauna No. 2 Karangmalang, Sleman 55281, Yogyakarta, Indonesia
[4]Department of Biology, Graduate School of Natural and Applied Sciences, Eskişehir Osmangazi Üniversitesi. Eskişehir 26040, Türkiye

Manuscript received: 1 July 2024. Revision accepted: 25 August 2024.

Abstract. *Kurniawati DY, Puspitasari Y, Yudhana A, Saputro AL, Dhamayanti Y, Purnomo A, Bayram M, Purnama MTE. 2024. Sex determination in Japanese quails (*Coturnix japonica*) based on head morphometry variation among age. Biodiversitas 25: 2740-2748.* Sex determining of the Japanese quail (*Coturnix japonica*) is very crucial to increase the economic value during the rearing period. This study aimed to investigate the potential age at which Japanese quail sex may be recognized using head morphometry assessment. Forty-three quail in all were reared at random and labeled numbers until they turned fifty days old. Without considering sex into account, measurements of each quail's head morphometry and body weight were performed on days 10, 20, 30, 40, and 50. Skull Length (SL), Cranial Length (CL), Viscerocranium Length (VL), Maximum Width of Neurocranium (MWN), Beak Width (BW), Zygomaticus Width (ZW), Skull Height (SH), and Bill Depth (BD) were the characteristics that were assessed. To categorize data according to age and sex, quail was verified on day 50 using observations of the abdominal cavity. As a result, initially, on day 20, considerable morphometric variations between male and female quail were observed for the morphometric parameters MWN, BW, ZW, and BD. It was reported that the male quail's MWN ($p<0.001$), BW ($p<0.001$), ZW ($p<0.001$), and BD ($p<0.001$) parameters were significantly wider than those of the females. A positive correlation was reported for SL, CL, VL, MWN, BW, ZW, SH, and BD parameters, despite the lack of significant differences in body weight. In conclusion, quail sex can be determined using head morphometry as early as 20 days of the rearing period.

Keywords: *Coturnix japonica*, domesticated animals, genetic diversity, head morphometry, sex determination

Abbreviations: DOQ: Day-old Quails, SL: Skull Length, CL: Cranial Length, VL: Viscerocranium Length, MWN: Maximum Width of Neurocranium, BW: Beak Width, ZW: Zygomaticus Width, SH: Skull Height, BD: Bill Depth, FM_L= Foramen Magnum Length, FM_W= Foramen Magnum Width

INTRODUCTION

In Indonesia, the livestock industry is growing increasingly prevalent as a means of subsistence; raising poultry farming is one of the most in-demand businesses (Prasetyani et al. 2021). The Japanese quail is a member of the genus Coturnix, family Phasianidae, and order Galliformes (Anderson and Holmes 2022). In Japan, the domestication of Japanese quail started in the eleventh century. Although it was first produced and cared for as a hobby, its short puberty age, affordable feed intake, and high egg production have allowed it to take the spotlight in the chicken industry (Çağlayan and Şeker 2015). Raising Japanese quails (*Coturnix japonica*) has become increasingly popular in nearby communities as a beginning livestock enterprise. It provides several benefits, one of which is the high productivity of egg production, which is predicted to be between 250 and 300 eggs annually (Zaheer 2015). Raising quails primarily serves to generate edible quail eggs. As a result, since female quails can lay eggs without the assistance of their male counterparts, male quails are frequently considered to have no economic value (Ayoola et al. 2014). If breeders plan to maintain a breeding operation, they only need a modest number of male quails—one male for every two to four females is advised. Male quails are thought to be inefficient in breeding because of their high upkeep needs. For more accurate estimations of expenses and more effective management, it is imperative to ascertain the sex of quails as promptly as conceivable (Okuno et al. 2020; Lovela et al. 2023).

Breeders have several difficulties when determining a quail's sex, one of which is the challenge of accurately sexing quails at three weeks of age. At this age, it's challenging to recognize which quail is which because in general, the males' chest feathers change color from white to reddish-brown, while the females' feathers remain the same color (Megawati et al. 2020; Hanafi et al. 2021). A further indicator of diversity between the sexes is the bigger body size of female quails (Kosshak et al. 2014).

Several metrics, including head length, bill depth, bill length, wing length, and tarsometatarsal length, have been employed in morphometric investigations to identify the sex of bird species (Arizaga et al. 2008; Hammouda and Selmi 2013; Hallgrimsson et al. 2016). Head morphometry evaluation can also be used to identify the sex of poultry, however, study on sexual dimorphic morphometry based on live bird heads is necessary (Gündemir et al. 2020). However, few of these studies have been done, possibly considering research using live birds, in particular small species, requires such careful handling. The morphometry of cranial bones is the main focus of the majority of studies on sexual dimorphism, particularly involving the skulls of deceased animals as their main study subjects (Pecsics et al. 2017; Sun et al. 2018; Szara et al. 2022).

A previous study has shown that gulls (*Larus michahellis*) exhibit sexual dimorphism in their heads, especially in the depth of their beaks (Pacheco et al. 2023). Males have larger skulls than females, according to a study on Turkey skull bones (*Meleagris gallopavo*) (Süzer et al. 2018). A prior study also shows that cranial morphometry can be used to determine sexual dimorphism in padovana chickens (Gallina padovana), with male animals typically having larger craniums than female animals. One of the factors for determining sexual dimorphism may be considered head morphometry measures (Verdiglione and Rizzi 2018).

The existence of sexual dimorphism in the heads of Japanese quails has not been thoroughly investigated. Thus, the objective was to investigate the age at which head morphometry evaluation could possibly be applied to determine the sex of Japanese quails. In addition to the conventional techniques that breeders frequently use, including body color and cloaca differentiation, it is expected that the detection of sexual dimorphism in the skull may provide a further method of early sex determination in Japanese quails. In the case of Japanese quail farming, this prospective substitute approach should increase management effectiveness and increase the reliability of cost projections.

MATERIALS AND METHODS

Ethical approval

This study received ethical approval from Universitas Airlangga with declaration number 399/HRECC.FODM/VII. An ethical declaration was carried out to avoid animal abuse and excessive stress during the study.

Experimental animals

Day-Old Quails (DOQ) were reared on a private farm in Tinjomoyo Village, Banyumanik, Semarang, Central Java. There were three cages utilized containing 15 quails, each measuring 60x40 cm. A total of 43 quails were randomly reared by considering the color of the feathers and inspection of the cloaca to predict the sex and labeled with numbers until they were 50 days old. Quails were provided with a regular diet (P-100®, New Hope, Indonesia) (Table 1) and drinking water ad libitum by adhering to normal rearing management protocols. The cage area was maintained at 20-25°C and 30-80% humidity, respectively. The constancy of the surrounding ambient temperature was further ensured by a thermostat-connected 15-watt incandescent bulb. During days 10, 20, 30, 40, and 50, quail body weight and head morphometry measurements were obtained among each quail without considering sex.

Head morphometry evaluation

The head morphometry method was carried out on live quail using a digital Vernier Caliper with an accuracy of 0.01 mm by referring to the landmark points in Figure 1. The following parameters were evaluated following landmarks: SL stands for skull length, CL for cranial length, VL for viscerocranium length, MWN for maximum width of neurocranium, BW for beak width, ZW for zygomaticus width, SH for skull height, and BD for bill depth.

The quail was ethically slaughtered on day 50 to evaluate the foramen magnum. The skull samples were immersed in a 3% NaOH solution for 3 minutes following the removal of the soft tissue and muscles. The skull was then dehydrated at 100°C for 30 minutes. Muscle and soft tissue remnants were carefully removed. The length (FM_L) and width (FM_W) of the foramen magnum were measured by referring to Figure 1. In addition, the ovarian hierarchy in the abdominal cavity was recognized to validate the genuine sex.

Table 1. Feed ingredients and nutrients content of basal diets

Ingredients (g/kg)	Diets	Nutrients	Diets
Corn	530	Metabolite energy (MJ/kg)	12.98
Soybean meal	336	Crude protein (g/kg)	227
Corn oil	60	Calcium (g/kg)	10
Dicalcium phosphate	16	Phosphorus (g/kg)	7.1
Calcium carbonate	17	Methionine & cysteine	9.0
Methionine	2.0	Lysine (g/kg)	11.8
Vitamin premix	25		
• Vitamin A (IU)	15000		
• Vitamin D3 (IU)	3750		
• Vitamin E (mg)	37.5		
• Vitamin K3 (mg)	2.55		
• Thiamin (mg)	3		
• Riboflavin (mg)	7.5		
• Vitamin B6 (mg)	4.5		
• Vitamin B12 (µg)	24		
• Niacin (mg)	51		
• Folic acid (mg)	1.5		
• Biotin (mg)	0.2		
	13.5		
• Pantothenic acid (mg)	250		
• Choline chloride (mg)	100		
• Antioxidant (mg)	25		
Mineral mix			
• Zinc (mg)	37.5		
• Manganese (mg)	37.5		
• Iron (mg)	37.5		
• Copper (mg)	3.75		
• Iodine (mg)	0.83		
• Sulfur	62.5		
• Selenium (mg)	0.23		
Salt	4.0		

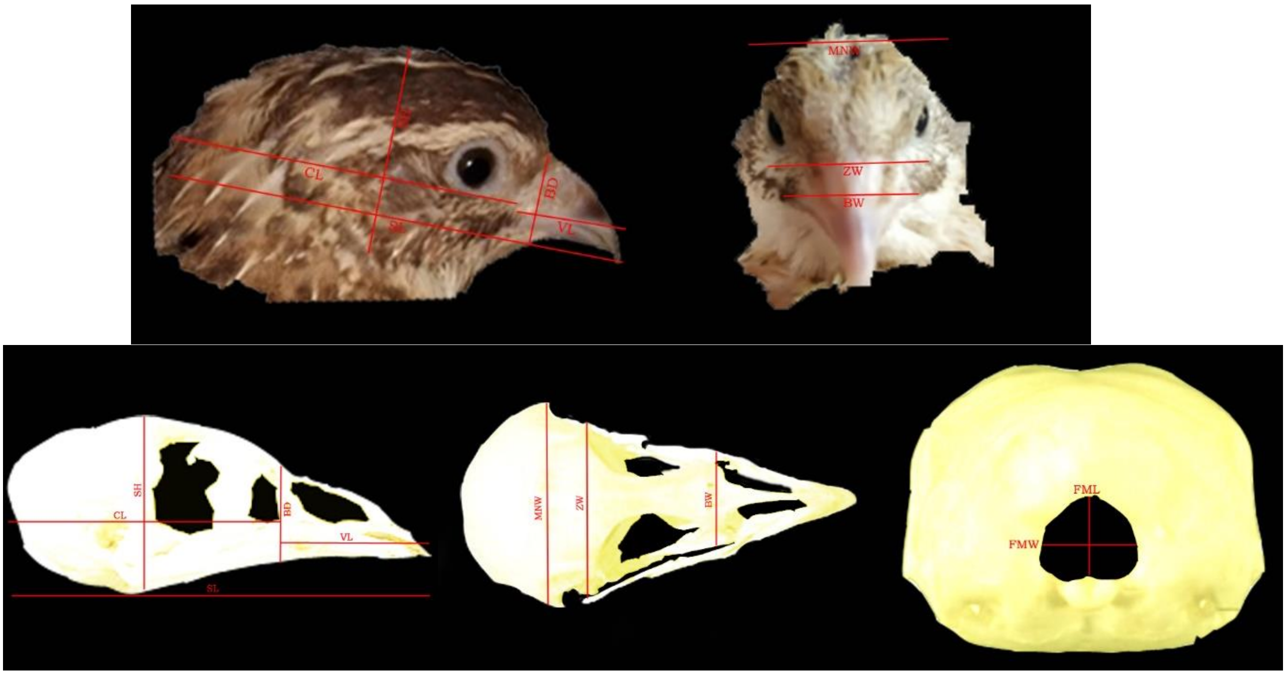

Figure 1. Head morphometry landmarks in quail. SL: Skull Length, CL: Cranial Length, VL: Viscerocranium Length, MWN: Maximum Width of Neurocranium, BW: Beak Width, ZW: Zygomaticus Width, SH: Skull Height, BD: Bill Depth, FM_L: Foramen Magnum Length, FM_W: Foramen Magnum Width

Data analysis

Sex validation from observations of ovarian hierarchy on day 50 was used as a basis for classifying head morphometry data previously collected randomly from 43 quail, thus they were then tabulated and analyzed statistically. Data were classified based on sex and age when data were collected. The homogeneity of variances was assessed using Levene's test, and the normality of the data was assessed using the Shapiro-Wilk statistic. When the normalcy assumption was unrevealed ($p<0.05$), the Kruskal-Wallis followed by Mann-Whitney tests were used to compare the data. Multivariate Analysis of Variance (MANOVA) was used to evaluate mean differences in head morphometry measurements and body weight between age and sex groups. In order to determine whether specific variables varied with sex in each age group, an independent sample t-test was also performed. Correlation test was used to evaluate the relationship between quail body weight and all head morphometry parameters. Then, the data were displayed in the table as mean±standard deviation. Data were considered significant at $p<0.05$. All stages of data analysis were performed in SPSS v.25 (IBM®, USA).

RESULTS AND DISCUSSION

Evaluation of quail body weight

We reported that 22 of the quails were male and the remaining fowl were female based on an examination of the abdominal cavity on the 50th day. Additionally, sex- and age-classified data produced several reports about body weight and head morphometry. Quail body weight observed during the rearing period did not show significant results ($p=0.730$) between males and females (Table 2). However, we reported a positive correlation between body weight and all head morphological parameters, as follows SL ($y=0.1148x+24.98$), CL ($y=0.0926x+18.129$), VL ($y=0.0509x+9.3818$), MWN ($y=0.0356x+12.315$), BW ($y=0.0329x+3.6798$), ZW ($y=0.034x+6.6458$), SH ($y=0.0362x+11.487$), and BD ($y=0.0229x+4.9876$) (Figure 2). On the other hand, quail body weight was negatively correlated with the FM_L ($y=-0.002x+2.8936$) and FM_W ($y=-0.0015x+3.6964$) of the foramen magnum (Figure 3). Despite body weight, the present study assumes that the finding is insufficient to distinguish between male and female quail. On the other hand, body weight might support the premise that improved growth performance and improved head morphometry occur simultaneously.

Evaluation of quail head morphometry

This study presented head morphometric data ie. MWN ($p<0.001$), BW ($p<0.001$), ZW ($p<0.001$), and BD ($p<0.001$) parameters demonstrated significant variations among sex and rearing age interactions. This interaction, which combines rising age and sex, has been investigated to determine whether it affects the parameters that are being monitored. In the interaction group, variables with a significant value of $p<0.05$ indicate that the head morphometric is influenced by the interaction between sex and age. Except for day 10, when the average value for female quails was higher than that of males, the measurements of these four variables were higher in male quails on days 20, 30, 40, and 50 (Table 3). It was considered that these factors might be used as variables in determining the quail's sex during the rearing period.

Table 2. Variation in quail body weight (gram) among ages

Sex	Ages					Multivariate interactions	
	Day 10	**Day 20**	**Day 30**	**Day 40**	**Day 50**	**Sex**	**Age**
Male (n=22)	28.95±3.59	80.73±10.74	110.37±10.04	142.59±11.27	150.47±12.36	0.730	0.001**
Female (n=21)	29.84±5.29	72.25±10.07	115.65±13.46	137.46±16.11	160.67±18.59		
p-value	0.235	0.003**	0.115	0.131	0.160		

Note: Significant at * p<0.05, ** p<0.01, *** p<0.001

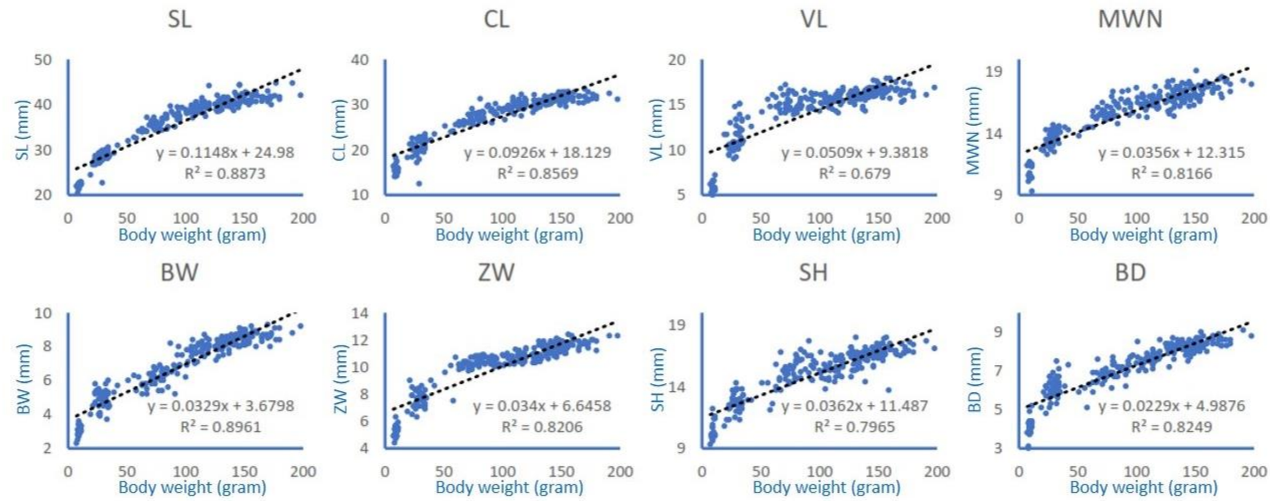

Figure 2. Correlation among quail body weight on respective head morphometry parameter. Note: SL: Skull Length, CL: Cranial Length, VL: Viscerocranium Length, MWN: Maximum Width of Neurocranium, BW: Beak Width, ZW: Zygomaticus Width, SH: Skull Height, BD: Bill Depth

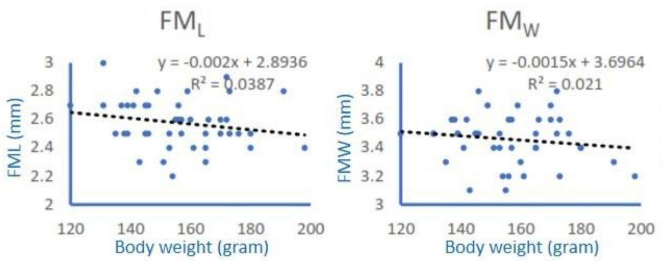

Figure 3. Correlation among quail body weight and foramen magnum morphometry on day 50. Note: FM_L: foramen magnum length, FM_W: foramen magnum width

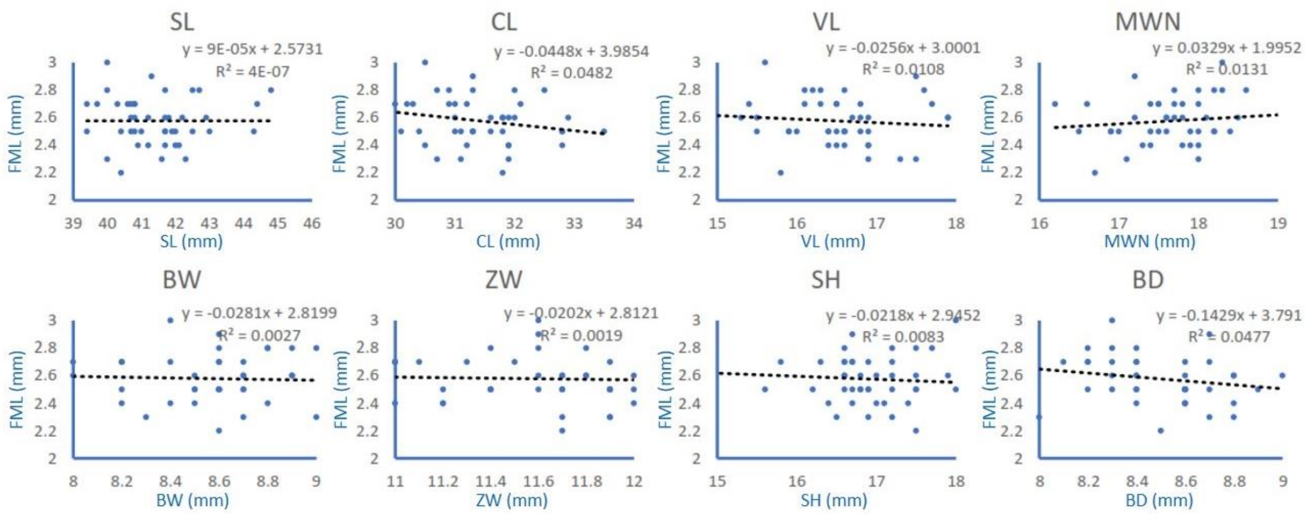

Figure 4. Correlation among foramen magnum length (FM_L) and respective head morphometry parameter on day 50. Note: Note: SL: Skull Length, CL: Cranial Length, VL: Viscerocranium Length, MWN: Maximum Width of Neurocranium, BW: Beak Width, ZW: Zygomaticus Width, SH: Skull Height, BD: Bill Depth

Table 3. Head morphometry evaluation of quail among sexes and ages

Variables	Sex	Ages					Multivariate interactions	
		Day 10	**Day 20**	**Day 30**	**Day 40**	**Day 50**	**Sex**	**Age**
Skull length (SL) (mm)	Male (n=22)	28.45±0.74	36.29±1.57	39.3±1.31	40.86±1.20	41.57±0.94	0.020*	0.160
	Female (n=21)	28.37±1.83	35.22±1.57	39.44±1.10	40.67±1.45	42.4±1.46		
	p-value	0.775	0.046*	0.437	0.916	0.459		
Cranial length (CL) (mm)	Male (n=22)	20.50±1.45	27.26±1.07	30.08±1.23	31.10±0.81	31.54±0.79	0.070	0.170
	Female (n=21)	21.18±2.36	26.75±1.68	29.47±1.08	30.48±0.84	31.3±0.90		
	p-value	0.062	0.305	0.072	0.024*	0.356		
Viscerocranium length (VL) (mm)	Male (n=22)	10.4±0.81	14.74±0.63	15.71±0.63	16.20±0.49	16.64±0.76	0.051	0.000***
	Female (n=21)	12.42±1.46	15.45±0.90	15.55±0.58	16.17±0.58	16.41±0.65		
	p-value	0.000***	0.000***	0.837	0.845	0.229		
Maximum width of neurocranium (MWN) (mm)	Male (n=22)	13.59±0.80	15.99±0.80	16.61±0.50	17.24±0.47	17.84±0.47	0.000***	0.003**
	Female (n=21)	13.75±0.62	15.61±0.89	16.35±0.63	16.91±0.63	17.51±0.66		
	p-value	0.727	0.074	0.059	0.024*	0.008**		
Beak width (BW) (mm)	Male (n=22)	4.84±0.51	6.41±0.42	8.00±0.29	8.42±0.24	8.73±0.26	0.000***	0.001**
	Female (n=21)	4.98±0.54	5.93±0.45	7.52±0.40	8.17±0.26	8.59±0.35		
	p-value	0.023*	0.000*	0.001**	0.001**	0.015*		
Zygomaticus width (ZW) (mm)	Male (n=22)	7.72±0.57	10.32±0.34	10.69±0.31	11.29±0.37	11.80±0.30	0.000***	0.002**
	Female (n=21)	7.74±0.65	10.21±0.69	10.53±0.27	11.15±0.38	11.55±0.40		
	p-value	0.741	0.429	0.018*	0.069	0.011*		
Skull height (SH) (mm)	Male (n=22)	12.80±0.53	15.31±0.83	15.65±0.88	16.40±0.57	16.92±0.92	0.080	0.790
	Female (n=21)	12.52±0.84	15.03±1.25	15.52±0.78	16.49±0.55	16.82±0.53		
	p-value	0.060	0.307	0.842	0.964	0.749		
Bill depth (BD) (mm)	Male (n=22)	6.20±0.66	6.96±0.48	7.61±0.32	8.20±0.27	8.51±0.27	0.000***	0.000***
	Female (n=21)	6.03±0.44	6.70±0.56	7.63±0.41	8.13±0.22	8.50±0.26		
	p-value	0.644	0.040*	0.462	0.537	0.650		

Note: Significant at * p<0.05, ** p<0.01, *** p<0.001

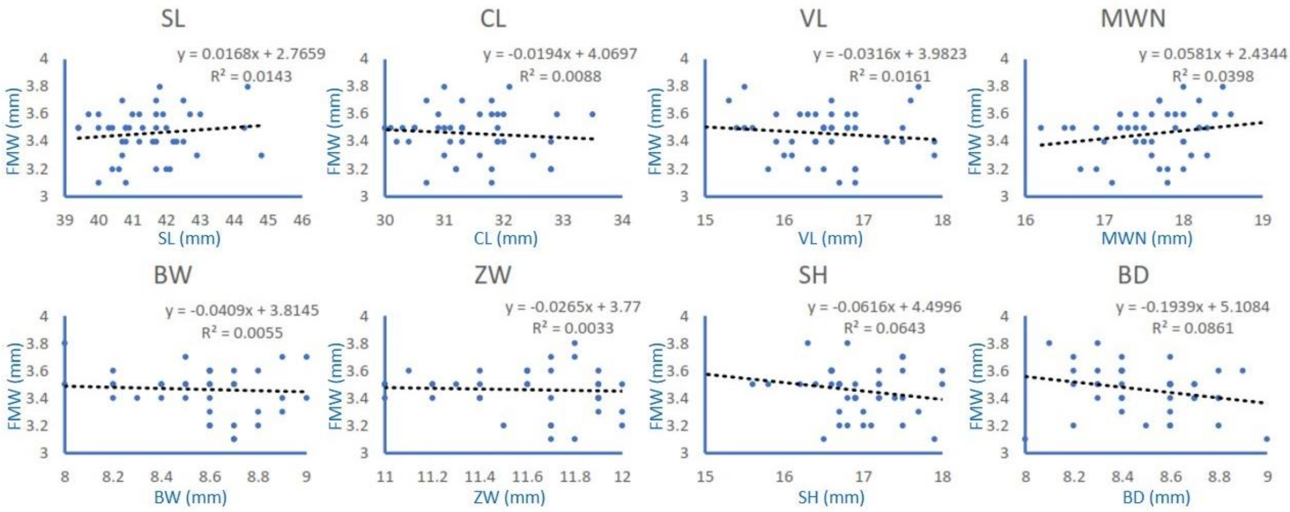

Figure 5. Correlation among foramen magnum width (FM_W) and respective head morphometry parameter on day 50. Note: Note: SL: Skull Length, CL: Cranial Length, VL: Viscerocranium Length, MWN: Maximum Width of Neurocranium, BW: Beak Width, ZW: Zygomaticus Width, SH: Skull Height, BD: Bill Depth

Table 4. Evaluation of the foramen magnum among sexes on day 50

Variables	**Sex**	**Day 50**	***p-value***
Foramen magnum length (FM_L) (mm)	Male (n=22)	2.61±0.16	0.155
	Female (n=21)	2.54±0.18	
Foramen magnum width (FM_W) (mm)	Male (n=22)	3.49±0.17	0.182
	Female (n=21)	3.42±0.18	

Note: Significant at * p<0.05, ** p<0.01, *** p<0.001

This study also reported no significant differences (p> 0.05) in the foramen magnum of male and female quail (Table 4). However, the present study revealed that there is a positive correlation between FM_L and MWN (y=0.0329x+1.9952) (Figure 4), FM_W and SL (y=0.0168x+2.7659), and MWN (y=0.0581x+2.4344) (Figure 5), respectively. These findings suggest that the foramen magnum has a correlation with the zygomatic bone in sculpting facial geometry, but it is not a variable for predicting sex.

Discussion

In the earlier study, the average weight of male quails at the age of 7 weeks was roughly 118.78 grams (Putra et al. 2018). In contrast, the study's female quails were reported to weigh 143 grams at the age of 7 weeks, which was a higher weight. Furthermore, a previous study reported that the body weight of female quail was around 139.80 grams at 7 weeks of age (Purnama et al. 2021), which means that the current study indicates that the average final weight of female quail is higher. The amount of feed consumed by quail is directly proportional to its average body weight; that is, the higher the average body weight, the more feed is consumed (Classen 2017). Feed intake levels are influenced by several characteristics, including age, production levels, activity, health, diet energy, and diet palatability in birds. When a quail ration has a low energy level, consumption of the ration tends to rise (Jahanian and Edriss 2015). Additionally, body weight measurements from live birds should be performed with moderation because the mass can vary depending on several factors, such as the bird's overall physiological state, its migratory condition, its reproductive status (e.g., if eggs are present in the female oviducts), and its health. For quail sexing, additional sex determination factors including field plumage traits should also be taken into account.

There are two phases of growth: the fast period lasts from day-old quail until puberty, and the slow stage starts after physical maturity. From hatch until they reach sexual maturity, quail grow quickly; but, as quail become older, their bone growth slows down (Agustono et al. 2019). Growth hormones also have an impact on quail output. While the estrogen in female quail increases fat growth and inhibits bone growth, testosterone in male quail plays a role in both suppressing fat growth and stimulating bone growth (Wilhelms et al. 2006; Dewi et al. 2024). When a quail reaches the culling period, their ovaries produce less estrogen, which causes a greater loss of bone tissue. According to a prior study, the estrogen generated by the developing fetus permanently demasculinates the female brain, eliminating the adult female's ability to engage in male sexual behavior. The suppression of estrogen formation in the female Japanese quail embryo has been used in experiments to validate the organisational effect of estrogen. These studies suggest that both the organisational effects of estrogens during early development and the activational effects of testosterone following aromatization to estrogen in the adult bird's brain account for the sexual dimorphism of copulatory behavior (Balthazart et al. 2009). Because of this hormonal imbalance, females acquire more fat than males while having a smaller frame and morphometric size (Agustono et al. 2024).

Feather color is the primary indicator of initial sex; males have blackish feather lines, while females have brownish feathers. These results align with the previous study, which found that feather color could predict sex 92.72% of the time (Tumbilung et al. 2014; Hidanah et al. 2023). It was additionally reported in another study that the method, which relied on the male quail's genital protuberance morphology, had a 99% accuracy rate. However, environmental and genetic factors affected the determination's accuracy (Dominchin et al. 2017). In another study, a mere two morphometric variables were used to build discriminant functions, which yielded 90% and 96% of correct sexual classification for juvenile birds, and head and forearm lengths for mature birds (Madsen et al. 2007). Comparing these categorization rates to those derived from cloacal inspection, they are substantially greater. However, with 92% accurate classification, cross-validation with a fresh sample of mature swans (*Coscoroba coscoroba*) revealed that the most dependable sexing method was based on a single metric (head length). According to that study, in many other bird species, discriminant functions might be a superior option to cloacal sexing (Calabuig et al. 2011).

This study revealed that the parameters of MWN, BW, ZW, and BD in male quails were significantly greater than those in females. Another study also presented that values for cerebrum length and cerebellum length in male quails were wider than in females, a characteristic that may be attributed to neural cavities in males. Variances in head morphometric parameters across several bird species have been reported in previous study (Igado and Aina 2017). According to a study done on Baltic herring gulls (*Larus argentatus argentatus*) over a range of age groups, head length and bill depth were the most reliable indicators of sex (Meissner et al. 2017). The most distinctive features of the sex in the Yellow-legged Gulls of the Istanbul area were likewise found to be these two structures. The rate of rise in bill depth and the fact that this increase lasts until the bird reaches the age of nine, as in the case of Herring Gulls, should be taken into consideration when using formulations derived from field investigations (Coulson et al. 1981). A study performed by Süzer et al. (2018) reported that the MWN, CL, and SH in male turkeys were wider than those in female turkeys, possibly due to the larger brain size and jaw strength in male turkeys compared to females. Another study performed by Hospitaleche and Tambussi (2006) also reported that the SL of male penguins (*Pygoscelis antarctica*) was wider than that of females. In padovana chickens, male individuals exhibited wider values for SH, SL, and MWN compared to females. Sexual dimorphism in head morphometric size is assumed to be influenced by distinct genetic activities in males and females (Verdiglione and Rizzi 2018). Additionally, a study by Firdaus et al. (2022) on muscovy ducks revealed that males had greater length, width, cranium height, mandibular length, and rostrum length.

Males and females can be distinguished from one another by their head and bill lengths. One advantage of these "skeletal" measurements is that they are unaffected by things like food availability, season, breeding cycle stage, moult, or wear. Furthermore, unlike other body characteristics that are useful in adult sex discrimination but have not typically been assessed in the field, such as footpad length, forearm length, or tarsus length, they are reliable and frequently measured in morphometrical investigations (Xirouchakis and Poulakakis 2008). The obtained data revealed that the following parameters i.e. MWN, BW, ZW, and BD represent sexual dimorphism in DOQ then continue to persist on the 10th, 20th, 30th, 40th, and 50th day. In general, the head morphometric of the male quail is larger than that of the female, excluding on day 10, where the parameters of MWN, BW, and ZW in female quails exhibited higher values than those in males. This could be correlated to a higher feed intake in female quails during that period. The feed intake of 2-week-old females is approximately 41.21 grams/quail/week, while males consume around 32.61 grams/quail/week (Purnama et al. 2021). The difference in feed intake results in faster growth in female quails compared to males on day 10, as evidenced by their higher weight and head morphometry.

A prior study investigated the geometric morphometrics among the sexes in quail skulls. The two groups' differences in shape were compared, and dorsal, caudal, and ventral perspectives were used to evaluate the landmarks that showed sex differences. The study found that the male and female samples' form variances were relatively close to one another. There was no clear distinction between males and females in the caudal aspect, despite the dorsal aspect showing more signs of difference. Still, one may argue that sex segregation within identical taxa utilizes the application of geometric form analysis. The longitudinal measurements revealed variations among males and females using standard morphometric methods in different skulls (Szara et al. 2022).

Radiographic morphometry can be used to indirectly assess the bone width in living animals. A previous investigation has revealed a statistically significant difference ($p<0.01$) in the humerus width between males and females. Nonetheless, this variable has a correlation with body weight, just like other measurements. This demonstrates that size dimorphism is more evident in the bones of pigeons than shape dimorphism. As a result, it was unsuccessful to distinguish the sex of the pigeons using only the analysis of variance of the radiography measures. This drawback does not exist with the discriminant function analysis, which enabled the accurate assignment of 81.4% of the cases. The head and the distal portion of the wing are the subjects of the variables utilized in the discriminant function (Szara et al. 2024).

In conclusion, the current study has revealed that there was no significant difference in body weight between male and female quail during the rearing period. This study has emphasized the results of using the morphometry of MWN, BW, ZW, and BD to identify the sex of quail. Male quails were reported to be wider (15.99±0.80; 6.41±0.42; 10.32±0.34; and 6.96±0.48) than females (15.61±0.89; 5.93±0.45; 10.21±0.69; and 6.70±0.56) at 20 days of age, respectively. This finding may support previous evidence that male quail have blackish feathers and cloacal protuberances. This study can offer evidence in grading quail growth performance because quail body weight also positively correlates with all head morphometric measures. A different approach to sex differentiation in Japanese quails, including DOQ, is head morphometric measurements, which measure the MWN, BW, ZW, and BD. Considering the enormous economic value difference between male and female quails, incorrect sex determination can have significant repercussions for farmers on a broader scale.

ACKNOWLEDGEMENTS

The author would like to thank the Dean of the Faculty of Health, Medicine, and Life Sciences, Universitas Airlangga, Surabaya, Indonesia for supporting facilities during this study. This study received no specific grant from funding agencies, the government, and the public community.

REFERENCES

Agustono B, Al Arif MA, Yunita MN, Purnama MTE, Ulkhaq F. 2019. Bioactivity of digestive enzymes and histological descriptions of jejunum of broilers supplemented with sunflower seed flour (*Helianthus Annuus* L). Indian Vet J 96 (8): 12-15.

Agustono B, Abidah Alfirdausy S, Warsito SH, Yunita MN, Lokapirnasari WP, Purnama MTE, Chhetri S, Windria S, Rahman MA. 2024. Influence of *Mauritia flexuosa* L. on broiler carcass mass and digestive organs temperature-exposed body mass. Indian Vet J 101 (2): 10-14. DOI: 10.62757/IVA.2024.101.2.10-14.

Anderson G, Holmes C. 2022. Galliformes: Species, varieties, and behavior. Gamebird Med Manag 8 (1): 13-35. DOI: 10.1002/9781119712244.ch3.

Arizaga J, Aldalur A, Herrero A, Galicia D. 2008. Sex differentiation of Yellow-legged Gull (*Larus michahellis lusitanius*): The use of biometrics, bill morphometrics and wing tip coloration. Waterbirds 31 (2): 211-219. DOI: 10.1675/1524-4695(2008)31[211:sdoygl]2.0.co;2.

Ayoola AA, Adeyemi OA, Egbeyale LT, Sogunle OM, Ekunseitan DA. 2014. Effects of sex and stocking density on growth performance and some physiological traits of Japanese quails (*Coturnix coturnix japonica*). Malays J Anim Sci 17 (2): 43-53.

Balthazart J, Cornil CA, Charlier TD, Taziaux M, Ball GF. 2009. Estradiol, a key endocrine signal in the sexual differentiation and activation of reproductive behavior in quail. J Exp Zool A Ecol Genet Physiol 311 (5): 323-345. DOI: 10.1002/jez.464.

Calabuig CP, Green AJ, Ferrer M, Muriel R, Moreira H. 2011. Sexual size dimorphism and sex determination by morphometric measurements in the Coscoroba Swan. Stud Neotrop Fauna Environ 46 (3): 177-184. DOI: 10.1080/01650521.2011.617545.

Classen HL. 2017. Diet energy and feed intake in chickens. Anim Feed Sci Technol 233: 13-21. DOI: 10.1016/j.anifeedsci.2016.03.004.

Coulson JC, Duncan N, Thomas CS, Monaghan P. 1981. An age-related difference in the bill depth of herring gulls *Larus argentatus*. Ibis 123 (4): 499-502. DOI: 10.1111/j.1474-919x.1981.tb04054.x.

Çağlayan T, Şeker E. 2015. Dağ nanesinin (*Mentha caucasica*) Japon bıldırcınlarının (*Coturnix coturnix japonica*) performans, bazı vücut ölçüleri ve canlı ağırlık arasındaki ilişkilerine etkisi. Eurasian J Vet Sci 31: 33-42. DOI: 10.15312/eurasianjvetsci.2015.168.

Dewi CMS, Dhamayanti Y, Fikri F, Purnomo A, Khairani S, Chhetri S, Purnama MTE. 2024. An investigation of syrinx morphometry and sound frequency association in lovebirds (*Agapornis fischeri*) chirps. F1000Research 11: 354. DOI: 10.12688/f1000research.108884.3.

Dominchin MF, Busso JM, Kembro JM, Marin RH, Guzmán DA. 2017. Divergent cloacal gland photo-responsiveness in male Japanese quail exposed to short days and associated differences in social interactions and reproduction. Poult Sci 96 (1): 5-13. DOI: 10.3382/ps/pew287.

Firdaus M, Samik A, Dhamayanti Y, Adikara RTS, Adikara HE, Eliyani H, Soeharsono S. 2022. Cranium morphometry for distinguishing male and female Muscovy duck (*Cairina moschata*) before sexual maturity. Ovozoa: J Anim Reprod 11 (2): 54-58. DOI: 10.20473/ovz.v11i2.2022.54-58.

Gündemir O, Pazvant G, İnce NG. 2020. The morphometric examination of head area of black headed gulls (*Larus ridibundus*) from Marmara Region. J Res Vet Med 39 (1): 49-53. DOI: 10.30782/jrvm.634404.

Hallgrimsson GT, Helgason HH, Palsdottir ES, Palsson S. 2016. Sexing adult and fledgling lesser black-backed gulls from morphometrics. Ringing Migr 31 (1): 68-73. DOI: 10.1080/03078698.2016.1190617.

Hammouda A, Selmi S. 2013. Morphometric sexing of Mediterranean Yellow-legged Gulls *Larus michahellis michahellis* breeding in the Gulf of Gabès, Southern Tunisia. Ostrich 84 (2): 119-122. DOI: 10.2989/00306525.2013.829131.

Hanafi UF, Dhamayanti Y, Soeharsono S, Wibawati PA, Prastiya RA. 2021. Hindlimb Osteometry of Lohmann broiler on 7, 21 and 35 days. Jurnal Medik Veteriner 4 (1): 23-36. DOI: 10.20473/jmv.vol4.iss1.2021.23-36. [Indonesian]

Hidanah S, Sabdoningrum EK, Chusniati S, Nurliyani, Khairullah AR, Nayan N. 2023. Effectiveness of *Phyllanthus niruri* and *Andrographis paniculata* extracts on egg quality in laying hens with avian pathogenic *Escherichia coli*. Jurnal Medik Veteriner 6 (3): 48-54. DOI: 10.20473/jmv.vol6.iss3.2023.48-54.

Hospitaleche CA, Tambussi C. 2006. Skull morphometry of Pygoscelis (Sphenisciformes): inter and intraspecific variations. Polar Biol 29: 728-734. DOI: 10.1007/s00300-006-0109-6.

Igado OO, Aina OO. 2017. Some aspects of the neurometrics and oculometrics of the Japanese quail (*Coturnix coturnix japonica*) in Nigéria. J Morphol Sci 27 (3-4): 133-135. DOI: 10.51929/jms.27.3-4.133.

Jahanian R, Edriss MA. 2015. Metabolizable energy and crude protein requirements of two quail species (*Coturnix japonica* and *Coturnix ypsilophorus*). J Anim Plant Sci 25 (3): 603-611.

Kosshak AS, Dim NI, Momoh OM, Gambo D. 2014. Effect of sex on carcass characteristics and correlation of body weight and blood components in Japanese quails. IOSR J Agric Vet Sci 7 (11): 72-76. DOI: 10.9790/2380-071137276.

Lovela AR, Lokapirnasari WP, Warsito SH, Prasinta R, Hapsari T, Andriani A. 2023. The quality of Japanese quail eggs after administration of *Bifidobacterium* sp. and *Guazuma ulmifolia* leaf extract. Jurnal Medik Veteriner 6 (1): 132-136. DOI: 10.20473/jmv.vol6.iss1.2023.132-136.

Madsen V, Dabelsteen T, Osorio D, Osorno JL. 2007. Morphology and ornamentation in male magnificent frigatebirds: Variation with age class and mating status. Am Nat 169 (S1): S93-S111. DOI: 10.2307/4125304.

Megawati NI, Dhamayanti Y, Purnama MTE, Soeharsono S, Yudhana A, Yunita MN. 2020. The growth patterns of broiler lohmann strains based on forelimb bone osteometry. Jurnal Medik Veteriner 3 (2): 216-223. DOI: 10.20473/jmv.vol3.iss2.2020.216-223.

Meissner W, Kośmicki A, Niemczyk A, Fischer I. 2017. Development of sexual dimorphism and sexing of Baltic herring gull (*Larus argentatus argentatus*) in successive age classes. Waterbirds 40 (1): 24-32. DOI: 10.1675/063.040.0104.

Okuno M, Miyamoto S, Itoh T, Seki M, Suzuki Y, Mizushima S, Kuroiwa A. 2020. Expression profiling of sexually dimorphic genes in the Japanese quail, *Coturnix japonica*. Sci Rep 10 (1): 20073. DOI: 10.1038/s41598-020-77094-y.

Pacheco MLM, Tavecchia G, Igual JM, Alonso-Álvarez C, Arizaga J, Galarza A, Oro D, Martínez-Abraín A. 2023. Yellow-legged gulls from the Mediterranean are not only larger but also allometrically longer-winged than those from the Cantabrian-Atlantic. Ardeola 70 (2): 225-240. DOI: 10.13157/arla.70.2.2023.ra5.

Pecsics T, Laczi M, Nagy G, Csörgő T. 2017. The cranial morphometrics of the wildfowl (Anatidae). Ornis Hung 25 (1): 44-57. DOI: 10.1515/orhu-2017-0004.

Prasetyani D, Ardianto DT, Firdaus AA. 2021. Integration of livestock supply chain strategy as part of the creative economy and creative industry in Indonesia: Literature review. IOP Conf Ser: Earth Environ Sci 902 (1): 012051. DOI: 10.1088/1755-1315/902/1/012051.

Purnama MTE, Ernanda EP, Fikri F, Purnomo A, Khairani S, Chhetri S. 2021. Effects of dietary supplementation with breadfruit leaf powder on growth performance, meat quality, and antioxidative activity in Japanese quail. Vet World 14 (7): 1946-1953. DOI: 10.14202/vetworld.2021.1946-1953.

Putra A, Dahlan I, Pratama A. 2018. Substitution of anchovy waste flour for fish meal as conventional feed on quail performance (*Coturnix-*

coturnix japonica). Indones J Agric Res 1 (2): 105-111. DOI: 10.32734/injar.v1i2.315.
Sun Y, Si G, Wang X, Wang K, Zhang Z. 2018. Geometric morphometric analysis of skull shape in the Accipitridae. Zoomorphology 137: 445-456. DOI: 10.1007/s00435-018-0406-y.
Süzer B, Serbest A, Arican I, Yonkova P, Yilmaz B. 2018. A morphometric study on the skull of the turkeys (*Meleagris gallopavo*). Uludağ Üniversitesi Veteriner Fakültesi Dergisi 37 (2): 93-100. DOI: 10.30782/uluvfd.427228.
Szara T, Duro S, Gündemir O, Demircioğlu İ. 2022. Sex determination in Japanese quails (*Coturnix japonica*) using geometric morphometrics of the skull. Animals 12 (3): 302. DOI: 10.3390/ani12030302.
Szara T, Gündemir O, Günay E, Gün G, Avanus K, Pazvant G. 2024. Sex determination in domestic rock pigeons (*Columba livia*) using radiographic morphometry. Acta Zool 105 (1): 38-45. DOI: 10.1111/azo.12452.
Tumbilung W, Lambey L, Pudjihastuti E, Tangkere E. 2014. Sexing based on morphology of quail (*Coturnix coturnix japonica*). Zootec 34 (2): 170-184. DOI: 10.35792/zot.34.2.2014.5982. [Indonesian]
Verdiglione R, Rizzi C. 2018. A morphometrical study on the skull of Padovana chicken. Ital J Anim Sci 17 (3): 785-796. DOI: 10.1080/1828051x.2017.1412810.
Wilhelms KW, Scanes CG, Anderson LL. 2006. Lack of estrogenic or antiestrogenic actions of soy isoflavones in an avian model: the Japanese quail. Poult Sci 85 (11): 1885-1889. DOI: 10.1093/ps/85.11.1885.
Xirouchakis SM, Poulakakis N. 2008. Biometrics, sexual dimorphism and gender determination of Griffon Vultures Gyps fulvus from Crete. Ardea 96 (1): 91-98. DOI: 10.5253/078.096.0110.
Zaheer K. 2015. An updated review on chicken eggs: Production, consumption, management aspects and nutritional benefits to human health. Food Nutr Sci 6 (13): 1208. DOI: 10.4236/fns.2015.613127.