Kafkas Universitesi Veteriner Fakultesi Dergisi
Journal Home-Page: http://vetdergikafkas.org
E-ISSN: 1309-2251

Kafkas Univ Vet Fak Derg
29 (5): 497-504, 2023
DOI: 10.9775/kvfd.2023.29499

Research Article

Radiographic Pelvimetry in Budgerigars with and without Egg Retention

Davut KOCA[1 (*)] Osman YILMAZ [2] M. Eren ŞAHİN [3] Talha AVCILAR [4]

[1] Department of Obstetrics and Gynecology, Faculty of Veterinary Medicine, Van Yüzüncü Yıl University, TR-65080 Van - TÜRKİYE
[2] Department of Anatomy, Faculty of Veterinary Medicine, Van Yüzüncü Yıl University, TR-65080 Van - TÜRKİYE
[3] Vetorka Veterinary Clinic, TR-16120 Bursa - TÜRKİYE
[4] Beta Veterinary Clinic, TR-16160 Bursa - TÜRKİYE

(*) **Corresponding author:** Davut KOCA
Phone: +90 432 225 1128 /21537
Fax: +90 432 225 1127
E-mail: davutkoca@yyu.edu.tr

How to cite this article?

Koca D , Yılmaz O, Şahin ME, Avcılar T: Radiographic pelvimetry in budgerigars with and without egg retention. *Kafkas Univ Vet Fak Derg*, 29 (5): 497-504, 2023.
DOI: 10.9775/kvfd.2023.29499

Article ID: KVFD-2023-29499
Received: 30.03.2023
Accepted: 29.08.2023
Published Online: 06.09.2023

ABSTRACT

Egg retention, particularly in budgerigars, is an important reproductive issue. This study aimed to obtain osteometric measurement values, determine the length/width ratios between measurement values, and reveal the biometric differences in X-ray images of the pelvis of normal and egg-retention budgerigars. Pelvimetric measurements (linear distance, angle, length/width) were obtained from ventrodorsal images of the pelvis of 15 normal and 15 egg-retention budgerigars. The measured values were subjected to statistical analysis. Examining the pelvimetric data showed that the average measurement values of L1 (cranial ilium width), L4 (middle pubis width), L5 (caudal pubis width), L6 (caudal ischium width), A1 (iliac arch), LA2 (left ischiopubic angle), and RA2 (left ischiopubic angle) were significantly higher in the normal group than those of the egg retention group ($P<0.05$). Additionally, all length/width ratio measurements were higher in egg retention budgerigars. However, while the mean length/width ratio measurement values of L7 (left iliopubic length)/L2 (preacetabular tubercle width), L8 (right iliopubic length)/L2, L9 (synsacrum length)/L2, L7/L3 (acetabula width), L8/L3, and L9/L3 were higher in egg retention budgerigars compared to the normal group, this difference was not statistically significant ($P>0.05$). A1, LA2, and RA2 measurement values in normal and egg retention budgerigars were respectively found at 113.93±3.39 (°) and 95.73±2.22 (°); 115.93±2.25 (°) and 104.67±2.32 (°); 115.13±2.10 (°) and 105.07±1.98 (°). Consequently, the osteometric measurement parameters of the pelvis in the normal and egg retention budgerigars were determined using X-ray images. The morphometric data acquired through this study is believed to hold potential value for veterinarians involved in clinically assessing egg retention in budgerigars.

Keywords: Bird, Budgerigars, Egg retention, Pelvis, Radiographic Pelvimetry

Introduction

Budgerigars, among the parrot species, are domesticated bird species spread worldwide from Australia. These birds can be small and long-tailed, with patterned wings and different colors. Owing to their attractive appearance, budgerigars are intensively bred as pets worldwide. In addition, budgerigars are among the most popular pets because they are easy to live in, train, buy, and inexpensive to meet their needs. Budgerigars average 18-20 cm in length and 30-40 g in weight, and their lifespan is between 6-8 years. It is noteworthy that these birds possess speech skills [1,2].

Many reproductive problems can occur in birds. One of these problems is egg retention. In avian practice, egg retention is defined as the inability of a bird to successfully pass an egg without assistance. Among bird species, it is more common in budgerigars, cockatiels, lovebirds, finches, and canaries. The causes of egg retention include vitamin deficiencies, metabolic calcium syndrome related to calcium exhaustion or lack of absorption or availability, systemic diseases, malformed eggs, obesity, malnourishment, heredity, and pelvic factors. In addition, the evaluation of avian reproductive anatomy is of vital importance for understanding this situation [3,4].

Imaging methods are widely used in many areas of veterinary medicine [5]. Among these imaging methods, radiography is critical [6]. Radiography is used in poultry and other animal species [3-6].

This study aimed to present useful information to the veterinary field as a result of the data obtained by

This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0)

comparing pelvic measurements in budgerigars with and without egg retention.

Material and Methods

Ethical Statement

All procedures were performed with the approval of the Van YYU Animal Experiments Local Ethics Committee (VAN YUHADYEK), approval number 2023/03-06.

Animals

This study was conducted between the years of 2018-2022. In this study, 30 budgerigars with 15 egg retention, and 15 without egg retention, between the ages of 1-2 were used. The mean age of normal budgerigars was 17.80±3.47 months, while the mean age of egg retention was 17.73±3.77 months. In addition, the mean body weights of normal and with egg retention budgerigars were calculated as 27.67±1.45 g and 32.40±2.06 g, respectively. The body weight of the egg retention budgerigars was measured together with the egg weight in the reproductive tract. Animal materials were obtained from private veterinary clinics in Bursa Province of Türkiye and the required permissions were obtained (permission approval number: BETA/RI-I). Radiographic images of the pelvis of birds were used. Budgerigars that were healthy and could lay eggs regularly were formed without the egg retention group *(Fig. 1-A)* while budgerigars that could not hatch their eggs naturally and had egg retention as a result of X-ray examination, and underwent the necessary intervention formed the egg retention group *(Fig. 1-B)*. Consequently, the study encompassed budgerigars that exhibited no anatomical disorders, neoplastic growths, infectious conditions, congenital irregularities, or traumatic skeletal system abnormalities upon examination. The images obtained in this study were retrospectively evaluated based on routine clinical examination procedures.

Radiological Imaging

The Has Vet 838R X-ray device was used for X-ray examination of normal and egg retention budgerigars.

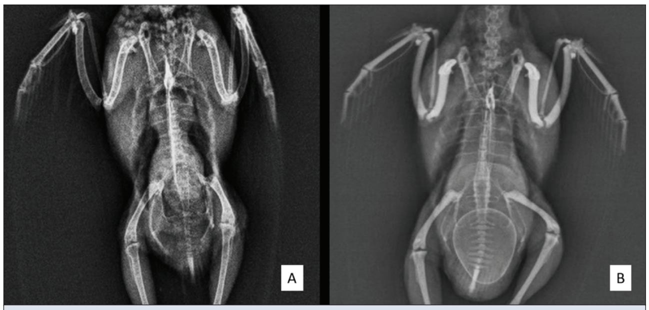

Fig 1. Ventrodorsal projection of the pelvis in normal (A) and egg retention (B) budgerigars

The birds were placed in the ventrodorsal position on a disposable drape laid on the X-ray table. During the shooting, the film-focus distance was determined as 10-20 cm for the stationary system in the parameters of the X-ray device. The exposure times were determined as 50-90 KV, 30 mA, 0.1-6.3 seconds. Thus, ventrodorsal images of the normal and egg-retention budgerigar pelvis were obtained, in which the anatomical structures were clearly visible. All image analyses were performed using open-source image analysis software (Horos v3.3.6, *https://horosproject.org/,* MacPro Quad Core, Apple, Inc. Cupertino, CA). Images were measured with electronic calipers using a software program.

Taking Measurements

Nomina Anatomica Avium was used to name the anatomical reference points used in the measurements [7]. The morphometric measurements were based on the measurement points specified in the literature [8]. Linear measurements taken from the ventrodorsal images of the pelvis of budgerigars were determined as L1 (Cranial ilium width), L2 (Preacetabular tubercle width), L3 (Acetabula width), L4 (Middle pubis width), L5 (Caudal pubis width), L6 (Caudal ischium width), L7 (Left iliopubic length), L8 (Right iliopubic length), and L9 (Synsacrum length). In addition, 3 angle measurement values were obtained: A1 (Iliac arch), LA2 (Left ischiopubic angle), and RA2 (Right ischiopubic angle). Finally, the length/width ratios between the morphometric measurements obtained from the ventrodorsal images of the budgerigar pelvis were evaluated. In this measurement value obtained from the pelvis, centimeters (cm) were used for linear measurements, and degrees (°) were used for angle measurements. The measurement points of the pelvis, abbreviations, and definitions of these measurements in the normal and egg retention budgerigars are presented in *Table 1*.

All the budgerigars were carefully positioned using a dorsal recumbency method within the positioning device, ensuring consistency across all ventrodorsal radiological images. To maintain an upright posture, the birds' necks were supported by a guillotine-like apparatus. A slight, gentle sway of the wings was observed in all specimens. The pelvic limbs were cautiously extended caudally and secured, thus standardizing the ventrodorsal alignment for all budgerigars. By adhering to these meticulous parameters, the objective was to achieve homogeneity, thereby safeguarding the precision of the measurements across all stances. Furthermore, to assess the reliability of the measurement outcomes, each pelvic dimension of the budgerigars underwent triple measurements by the same anatomist. The resulting average of these measurements was subsequently utilized for analysis.

Table 1. Measurement points, abbreviations, and explanation of the pelvis in budgerigars with normal and egg retention

Abbreviation	Measurements	Definition
Linear distances (cm)		
L1	Cranial ilium width	Horizontal distance greatest width between the cranial end of the os ilium
L2	Preacetabular tubercle width	Horizontal distance greatest width between the preacetabular tubercle
L3	Acetabula width	Horizontal distance between greatest width between the both acetabula (pelvis width)
L4	Middle pubis width	Horizontal distance between greatest width between the middle pubis
L5	Caudal pubis width	Horizontal distance between greatest width between the caudal end of the os pubis
L6	Caudal ischium width	Hhorizontal distance between smallest width between the caudal end of the os ischii
L7	Left iliopubic length	Distance between the cranial end of the left ilium and caudal end of the left pubis.
L8	Right iliopubic length	Distance between the cranial end of the right ilium and caudal end of the right pubis.
L9	Synsacrum length	Distance between the cranial and caudal end of the synsacrum.
Angle measurements (°)		
A1	Iliac arch	The angle between the cranial ilium arch
LA2	Left ischiopubic angle	The angle between the caudal point of the left ischium with the left pubis in the ventral image
RA2	Right ischiopubic angle	The angle between the caudal point of the right ischium with the right pubis in the ventral image
Ratios (length/width)		
L7/L1: Left iliopubic length/Cranial ilium width L8/L1: Right iliopubic length/Cranial ilium width L9/L1: Synsacrum length/Cranial ilium width L7/L2: Left iliopubic length/Preacetabular tubercle width L8/L2: Right iliopubic length/Preacetabular tubercle width L9/L2: Synsacrum length/Preacetabular tubercle width L7/L3: Left iliopubic length/Acetabula width L8/L3: Right iliopubic length/Acetabula width L9/L3: Synsacrum length/Acetabula width		L7/L4: Left iliopubic length/Middle pubis width L8/L4: Right iliopubic length/Middle pubis width L9/L4: Synsacrum length Middle pubis width L7/L5: Left iliopubic length/Caudal pubis width L8/L5: Right iliopubic length/Caudal pubis width L9/L5: Synsacrum length/Caudal pubis width L7/L6: Left iliopubic length/Caudal ischium width L8/L6: Right iliopubic length/Caudal ischium width L9/L6: Synsacrum length/Caudal ischium width

Statistical Analysis

In the calculation of the sample size of this study, which was carried out to determine the morphometric measurements of the pelvis radiologically in normal and egg-retention budgerigars, Power of test was determined by taking at least 80% and Type-1 error 5% for each variable. Shapiro-Wilk (n<50) and Skewness-Kurtosis tests were used to determine whether the continuous measurements in the study were normally distributed. Parametric tests were performed because measurements were normally distributed. Descriptive statistics for the study variables are expressed as mean, standard deviation, median, minimum, maximum, number (n), and percentage (%). "Independent T-test" was performed to compare the measurements according to the groups. The statistical significance level (α) was taken as 5% in the calculations and the SPSS (IBM SPSS for Windows, ver. 26) statistical package program was used for analysis.

Results

In this study, linear morphometric measurements were obtained from 9 parameters using radiological images of the ventrodorsal projection of the pelvis in normal and egg-retention budgerigars. Three measurement values were determined iliac arch, right ischiopubic angle, and left ischiopubic angle. The osteometric reference points used for the pelvic measurements of budgerigars are shown in *Fig. 2-A,B*. Finally, a total of 18 parameter ratio measurement values of the pelvis of budgerigars were calculated using the ratios of length and width measurements in morphometric measurements. The comparative statistical differences between these linear

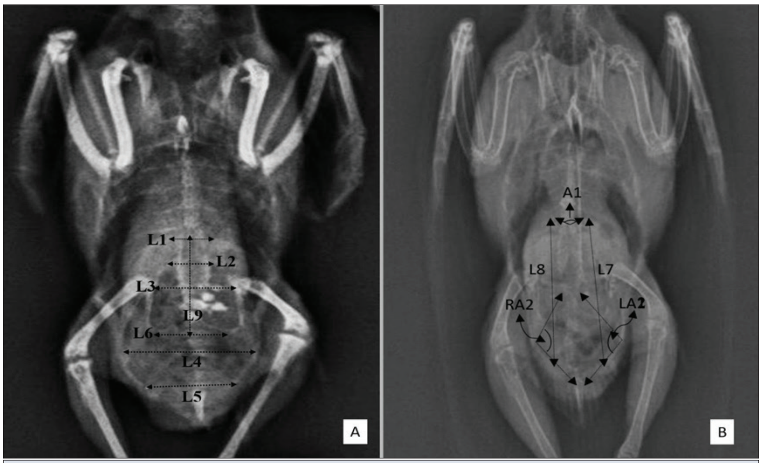

Fig 2. Ventrodorsal radiograph, pelvis measurements of egg retention (A) and normal (B) budgerigars, measurements: L1 (cranial ilium width), L2 (preacetabular tubercle width), L3 (acetabula width), L4 (middle pubis width), L5 (caudal pubis width), L6 (caudal ischium width), L7 (left iliopubic length), L8 (right iliopubic length), L9 (synsacrum length), A1 (iliac arch), LA2 (left ischiopubic angle), RA2 (right ischiopubic angle)

Table 2. *Descriptive statistics and comparison of pelvimetric measurement values in budgerigars with normal and egg retention*

Measurement Parameters	Normal (n=15)					Egg Retention (n=15)					P
	Mean	Std. Dev.	Median	Min.	Max.	Mean	Std. Dev.	Median	Min.	Max.	
L1	.851	.022	.850	.810	.890	.732	.037	.730	.660	.790	.001
L2	.991	.100	.990	.790	1.140	.981	.079	.970	.870	1.200	.779
L3	1.200	.028	1.190	1.160	1.250	1.194	.024	1.190	1.160	1.230	.526
L4	1.341	.072	1.360	1.150	1.430	1.197	.065	1.190	1.110	1.320	.001
L5	1.130	.111	1.170	.930	1.270	.895	.081	.880	.780	1.100	.001
L6	1.170	.035	1.180	1.100	1.230	.859	.062	.870	.760	.970	.001
L7	2.835	.077	2.850	2.690	2.970	2.846	.064	2.860	2.720	2.930	.682
L8	2.862	.048	2.860	2.780	2.950	2.851	.054	2.860	2.770	2.970	.573
L9	2.134	.041	2.140	2.050	2.200	2.144	.050	2.150	2.070	2.210	.553
A1	113.933	3.390	115.000	108.000	119.000	95.733	2.219	95.000	93.000	99.000	.001
LA2	115.933	2.251	116.000	112.000	119.000	104.667	2.320	105.000	101.000	109.000	.001
RA2	115.133	2.100	115.000	111.000	118.000	105.067	1.981	105.000	101.000	108.000	.001

**P<0.05; Independent sample T-test*

measurements, angle, and ratio measurements between the groups are presented in *Table 2* and *Table 3*. Statistically significant differences (P<0.05) between the measurement values in the tables were noted.

Comparative descriptive statistics of pelvimetric measurement values in normal and egg retention budgerigars are presented in *Table 2*. According to the table data, it was determined that other measurements, except for the L7 and L9 measurement values, were higher in normal laying budgerigars than in egg retention budgerigars. In addition, the mean measurement values of L1, L4, L5, L6, A1, LA2, and RA2 were significantly higher in the normal group than in the egg retention group (P<0.05). However, there was no statistically significant difference between the mean linear measurement values of L2, L3, L7, L8, and L9 of the pelvis of normal and egg retention budgerigars (P>0.05). Angle measurement values in normal and egg retention budgerigars were 113.93±3.39 (°) and 95.73±2.22 (°) respectively for iliac arch, 115.93±2.25 (°) and 104.67±2.32 (°) respectively for left ischiopubic angle; and 115.13±2.10 (°) and 105.07±1.98 (°) respectively for right ischiopubic angle.

The descriptive statistics and comparison of the ratios between the pelvimetric measurement values in normal and egg retention budgerigars are presented in *Table 3*. When we look at the table data in general, it was observed

Table 3. *Descriptive statistics and comparison of the ratios between pelvimetric measurement values in in budgerigars with normal and egg retention*

Ratios (length/ width)	Normal (n:15)					Egg Retention (n:15)					P
	Mean	Std. Dev.	Median	Min.	Max.	Mean	Std. Dev.	Median	Min.	Max.	
L7/L1	3.332	.113	3.326	3.112	3.561	3.897	.202	3.887	3.654	4.364	.001
L8/L1	3.364	.119	3.356	3.135	3.605	3.904	.207	3.917	3.564	4.348	.001
L9/L1	2.508	.088	2.506	2.303	2.651	2.936	.166	2.945	2.620	3.221	.001
L7/L2	2.891	.325	2.869	2.482	3.696	2.917	.233	2.960	2.358	3.225	.804
L8/L2	2.918	.317	2.859	2.527	3.570	2.924	.246	3.010	2.350	3.345	.959
L9/L2	2.175	.230	2.155	1.877	2.734	2.196	.163	2.216	1.792	2.483	.772
L7/L3	2.365	.105	2.367	2.187	2.560	2.385	.080	2.403	2.244	2.504	.563
L8/L3	2.386	.058	2.376	2.306	2.521	2.389	.063	2.372	2.301	2.560	.896
L9/L3	1.779	.053	1.782	1.691	1.856	1.796	.049	1.802	1.724	1.889	.370
L7/L4	2.120	.142	2.082	1.986	2.487	2.385	.150	2.420	2.142	2.622	.001
L8/L4	2.140	.121	2.142	2.000	2.417	2.390	.153	2.356	2.181	2.628	.001
L9/L4	1.595	.100	1.560	1.470	1.860	1.797	.092	1.840	1.580	1.940	.001
L7/L5	2.533	.272	2.475	2.118	3.118	3.205	.304	3.172	2.609	3.744	.001
L8/L5	2.558	.285	2.424	2.282	3.108	3.210	.287	3.241	2.600	3.667	.001
L9/L5	1.909	.213	1.830	1.640	2.300	2.412	.192	2.390	2.010	2.720	.001
L7/L6	2.425	.089	2.433	2.261	2.544	3.329	.266	3.247	2.938	3.789	.001
L8/L6	2.448	.086	2.441	2.309	2.588	3.334	.241	3.291	3.033	3.803	.001
L9/L6	1.825	.057	1.817	1.740	1.920	2.507	.189	2.471	2.155	2.797	.001

**P<0.05; Independent sample T-test*

that all the length/width ratio measurement values of the budgerigars were higher in the egg retention budgerigars than in the normal group. However, L7/L1, L8/L1, L9/L1, L7/L4, L8/L4, L9/L4, L7/L5, L8/L5, L9/L5, L7/L6, L8/L6, and L9/L6 the length/width ratio measurement values were found to be statistically significantly higher in egg retention budgerigars compared to the normal group. No statistically significant differences were found between the other length/width ratio measurements (L7/L2, L8/L2, L9/L2, L7/L3, L8/L3, and L9/L3) (P>0.05).

Discussion

Osteometric analyses in animals provide morphometric data for important scientific fields such as developmental, evolutionary, and forensic sciences. In addition, these morphometric data are frequently used for research on different animal species, determining morphological variations within species, taxonomic classification of animals, and determination of sexual dimorphism [9,10]. In addition, knowing the shape, morphologic, and morphometric features of the pelvis in birds, revealing allometric and phylogenic features, determining the ecological diversity, diversifying the locomotor modes, and evaluating the pathological conditions related to the pelvis are of great importance [2-4,11,12]. Exotic pet animals (such as birds, small mammals, and reptiles) medicine, and surgery have made great progress depending on developments in computer technologies, especially in the field of medical imaging. Diagnostic imaging modalities such as digital radiography and computed tomography are routinely used to examine any anatomical structure and to evaluate the efficacy of diagnosis, and treatment of various diseases in these animals [13]. In recent years, radiographic anatomical descriptions of other bones in the body, including the pelvis, have been made, especially for bird species such as parrots, partridges, ducks, and some raptors. In this way, the morphological features of osteological structures in radiological images have been determined [14-17]. This study was performed to obtain pelvimetric measurement values (linear osteometric measurements and angle), to determine the length/width ratios between pelvimetric measurements, and to determine the correlations between these measurements values using ventrodorsal X-ray images of the pelvis of normal and egg retention budgerigars.

Regarding the determination of the morphological and morphometric features of the pelvis of birds; common hawk cukoo *(Hierococcyx varius)* and yellow billed babbler *(Argya affinis)* [18], ostrich *(Struthio camelus),* emu *(Dromaius novaehollandiae),* domestic fowl *(Gallus gallus* *domesticus)* and duck *(Anas platyrhynchos domesticus)* [19], blue and yellow macaw *(Ara ararauna)* [20], Guinea fowl and pigeon [21], Indian eagle owl *(Bubo bengalensis)* [22], Chinese goose *(Anser cygnoides)* [23], peahen *(Pavo cristatus)* [24], crested serpent eagle *(Spilornis cheela)* and brown wood owl (*Strix leptogrammica)* [25], emu *(Dromaius novaehollandiae)* [26], ostrich *(Struthio camellus)* [27], domestic duck *(Anas platyrhynchos domesticus)* [28], peacock and peahen [29], Japanese quail *(Coturnix coturnix japonica)* [30], scientific studies have been carried out on many bird species. In the present study, comparative descriptive statistics of pelvimetric measurement values in normal and egg retention budgerigars were examined. Accordingly, the mean measurement values of L1, L4, L5, L6, A1, LA2, and RA2 were significantly higher in the normal group than in the egg retention group ($P<0.05$). Based on these findings, we concluded that the pelvis of normally laying budgerigars was larger than that of the egg retention group. This may cause the egg to protrude more easily from the pelvic canal. In addition, there was no statistically significant difference between the mean linear measurement values of L2, L3, L7, L8, and L9 taken from the pelvis of normal and egg retention budgerigars ($P>0.05$). In this case, it is thought that this cause egg retention by causing further elongation of the pelvic canal.

According to some studies, on the egg retention problem, one or more eggs through cloaca, the oversized or malformed eggs, and deformed egg maternal abnormalities include a misshapen pelvis, reproductive disorders such as an oviducal stricture, dysfunction of oviductal muscle, oviduct and cloaca damage, or a nonreproductive mass such as an abscess or cystic calculi, or a complication during oviposition such as an egg fractures within the or two eggs try to pass through the pelvis [31-33]. Additionally, vitamin deficiency, systemic disease, disorders of calcium metabolism, improper nesting site, improper temperature, malnutrition, dehydration, and poor physical condition of the female may all lead to egg retention [33,34]. Delving into the multifaceted causes of egg retention, the study directed its attention towards discerning pelvic dimensions and uncovering morphometric insights within both typical budgerigars and those experiencing egg retention. The premise underlying this focus was the potential influence of pelvic bone structure in precipitating such conditions. The findings from this analysis are anticipated to furnish crucial supplementary parameters, valuable for the comprehensive clinical assessment of egg retention, and even extend their utility to the selection of breeding candidates.

Egg dimensions exhibit variability corresponding to the age of the hens, while feeding and management practices distinctly influence egg size [33]. Concurrently, researchers have indicated a positive correlation between pelvic length and body mass, with an observed decrease in relative egg size as pelvic length extend [34-36]. Furthermore, findings suggest a negative relationship between egg mass and female body mass [37]. In summary, a prevailing trend among birds indicates that the proportional dimensions of eggs tend to rise as pelvis size decreases overall [36]. Given the study's primary emphasis on pelvis morphometrics, metrics like egg size or egg mass remained unattainable. Consequently, an exploration of the correlation between pelvis size and egg dimensions could not be undertaken. However, drawing from analogous measurements in existing research, there exists potential for a comprehensive clinical investigation into the intricate interplay between pelvis size and egg dimensions.

In the process of reviewing the literature, no specific measurement parameters were identified that encompassed the length/width index measurements of avian pelvises. Nevertheless, a study by Anten-Houston et al.[35] addressed this gap by examining pelvis dimensions across 146 bird species. The study underscored the significance of discerning morphometric linear measurements, including pelvis length and width, as crucial for unveiling insights into matters such as locomotor behaviors, ecological diversity, and phylogenetic attributes within avian populations. In this study, when the ratios between the pelvimetric measurement values in normal and egg retention budgerigars were examined, it was observed that all the length/width ratio measurement values of the pelvis of budgerigars were higher in egg retention budgerigars than in the normal group. In addition, although the mean length/width ratio measurement values of L7/L2, L8/L2, L9/L2, L7/L3, L8/L3, and L9/L3 were higher in egg retention budgerigars compared to the normal group, this difference was not statistically significant ($p>0.05$). These findings lead to the conclusion that a higher length/width ratio may result in a probability of egg retention in budgerigars.

There were some limitations in our study. Firstly, in the presented study, we only took morphometric measurements from the ventrodorsal images of normal and egg-retention budgerigars aged 1-2 years. It could be evaluated by taking measurements comparatively in different age groups or by laterolateral and dorsoventral projection. However, we were only able to access ventrodorsal radiological images of normal and egg retetion budgerigars with this age group. Another limitation is that in this study, measurements were obtained on X-ray images since it was affordable. Advanced medical imaging methods such as Computed Tomography (CT), Magnetic resonance imaging (MRI), or measurements could have been taken by making 3D models on these images, but these imaging methods could not be used due to the expense of these devices and the need for specialist personnel. Finally, besides pelvic measurements of budgerigars, detailed assessments of relationships could have been conducted by including measurements of body length, egg size, and egg mass. However, in this study, we focused on the morphometric pelvic measurements of both normal and egg-retained budgerigars.

In this study, radiographic pelvimetry of normal and egg-retention budgerigars was first evaluated in a comparative and comprehensive manner. With regard to the pelvis of female budgerigars, important descriptive morphometric data that could assist clinician veterinarians in the evaluation of radiographic images in various clinical application areas and could serve as a basis for future studies were obtained.

Availability of Data and Materials

The data sets generated for this study are available from the corresponding author (D. Koca) on reasonable request.

Acknowledgement

The authors thank Beta and Vetorka veterinary clinics' full teams for their assistance in the follow-up of the data and the conduct of this study.

Funding Support

There is no financial support.

Ethical Statement

All procedures were performed with the approval of the Van YYU Animal Experiments Local Ethics Committee (VAN YUHADYEK), approval number 2023/03-06.

Competing Interests

The authors declared that there is no conflicts of interest.

Author Contributions

D.K., O.Y. conceived, designed, and supervised the research procedure. M.E.S., T.A. collected data. D.K., O.Y., M.E.S., T.A. performed the anatomical analysis and measurements. D.K., O.Y. performed the statistical analysis, the imaging stage, and the language editing of the final manuscript. All authors contributed to the critical revision of the manuscript and have read and approved the final version

References

1. Kubiak M: Budgerigars and cockatiels. **In**, Kubiak M (Ed): Handbook of Exotic Pet Medicine, 141-164, Wiley-Blackwell Publishing, 2020.

2. Kılıcarslan R: Üreme ve pediatri. **In,** Ozsoy S (Ed): Papağangil ve Ötücü Kafes Kuşu Hastalıkları. 245-259, Nobel Publishing, İstanbul, 2012.

3. Reddy BS, Sivajothi S: Egg binding in budgerigar *(Melopsittacus undulatus)* an emergency condition. *Int J Avian Wildl Biol,* 3 (5): 352-353, 2018. DOI: 10.15406/ijawb.2018.03.00119

4. Rosen LB: Avian reproductive disorders. *J Exot Pet Med,* 21 (2): 124-131, 2012. DOI: 10.1053/j.jepm.2012.02.013

5. Farhad A, Masoud S, Shervin B: Effect of citric acid versus EDTA on radiographic root development in regenerative endodontic treatment: An animal study. *J Endod,* 48 (4): 535-541, 2022. DOI: 10.1016/j.joen.2022.01.001

6. Klever J, de Motte A, Meyer-Lindenberg A, Brühschwein A: Evaluation and comparison of self-made and commercial calibration markers for radiographic magnification correction in veterinary digital radiography. *Vet Comp Orthop Traumatol,* 35 (1): 010-017, 2022. DOI: 10.1055/s-0041-1735316

7. Baumel JJ, Witmer LM: Osteology. **In,** Baumel JJ, King AS, Breazile JE, Evans HE, Van den Berge JC (Eds): Handbook of Avian Anatomy: Nomina Anatomica Avium, 2nd ed., 45-132, Publications of the Nuttall Ornithological Club, USA, 1993.

8. Von den Driesch A: A Guide to the Measurement of Animal Bones From Archaeological Sites. 136, Peabody Museum Press, 1976.

9. Pitakarnnop T, Buddhacha K, Euppayo T, Kriangwanich W, Nganvongpanit K: Feline *(Felis catus)* skull and pelvic morphology and morphometry: Gender-related difference? *Anat Histol Embryol,* 46 (3): 294-303, 2017. DOI: 10.1111/ahe.12269

10. Yilmaz O, Demircioglu I: Computed tomography-based morphometric analysis of the hip bones *(Ossa coxae)* in Turkish Van cats. *Kafkas Univ Vet Fak Derg,* 27 (1): 7-17, 2021. DOI: 10.9775/kvfd.2020.24449

11. Frank TM, Dodson P, Hedrick BP: Form and function in the avian pelvis. *J Morphol,* 283 (6): 875-893, 2022. DOI: 10.1002/jmor.21479

12. Shatkovska OV, Ghazali M, Mytiai IS, Druz N: Size and shape correlation of birds' pelvis and egg: Impact of developmental mode, habitat, and phylogeny. *J Morphol,* 279 (11): 1590-1602, 2018. DOI: 10.1002/jmor.20888

13. Krautwald-Junghanns ME, Pees M, Reese S, Tully T: Diagnostic Imaging of Exotic Pets: Birds, Small Mammals, Reptiles. 453, Mason Publishing, London, UK, 2011.

14. Cavinatto CC, Armando APRN, Cruz LKS, Lima EMM, Santana MIS: Descrição anatômica de esqueletos de papagaios do gênero Amazona através da utilização de radiografias. *Pesqui Vet Bras*, 36 (2): 123-130, 2016. DOI: 10.1590/S0100-736X2016000200010

15. Smith BJ, Smith SA: The humeroscapular bone of the great horned owl *(Bubo virginianus)* and other raptors. *Anat Histol Embryol,* 21 (1): 32-39, 1992. DOI: 10.1111/j.1439-0264.1992.tb00316.x

16. Silva IA, Vieira LC, Mancini VRM, Faillace ACL, Santana MIS: Radiographic anatomy of the cockatiel *(Nymphicus hollandicus)* axial and appendicular skeleton. *Anat Histol Embryol,* 49 (2): 184-195, 2020. DOI: 10.1111/ahe.12510

17. Harcourt-Brown N: Radiographic morphology of the pelvic limb of falconiformes and its taxonomic implications. *Neth J Zool,* 51 (2): 155-178, 2001. DOI: 10.1163/156854201X00251

18. Supriya B, Bharath Kumar ML, Jamuna KV: Comparative morhological study of os coxae and synsacrum bones of common hawk cukoo *(Hierococcyx varius)* and yellow billed babbler *(Argya affinis). Int J Curr Microbiol App Sci,* 9 (10): 1284-1288, 2020. DOI: 10.20546/ijcmas.2020.910.154

19. Rajani CV, Patki HS, Wilson HM, Surjith K: Comparative morphological studies of the pelvic limb bones in ostrich *(Struthio camelus)*, emu *(Dromaius novaehollandiae)*, domestic fowl *(Gallus gallus domesticus)* and duck *(Anas platyrhynchos domesticus). Indian J Anim Res,* 53 (11): 1445-1449, 2019.

20. Sathyamoorthy OR, Churchil RR, Karunakaran N: Gross anatomical studies on the pelvic girdle of blue and yellow macaw *(Ara ararauna). J Entomol Zool Stud,* 7 (6): 694-698, 2019.

21. Lavanya C, Jayachitra C, Iniyah K, Balasundaram K: Comparative anatomy of os coxae in guinea fowl and Pigeon. *Int J Curr Microbiol Appl Sci,* 6 (9): 3655-3659, 2017. DOI: 10.20546/ijcmas.2017.609.449

22. Sarma K, Suri S, Sasan JS: Gross anatomical studies on os coxae of Indian eagle owl *(Bubo bengalensis). Explor Anim Med Res,* 8 (2): 208-210, 2018.

23. Sathyamoorthy OR, Chruchil RR, Dhamotharan, : Morphological and morphometric studies on the pelvic girdle of Chinese goose *(Anser cygnoides). Ind J Vet Anim Sci Res,* 49 (4), 1-9, 2020.

24. Sreeranjini AR, Ashok N, Indu VR, Lucy KM, Syam KV, Chungath JJ, Harshan K: Morphological studies on the pelvic girdle of a peahen *(Pavo cristatus). J Indian Vet Assoc,* 9 (3): 46-48, 2011.

25. Choudhary OP, Arya RS, Kalita PC, Doley PJ, Rajkhowa TK, Kalita A: Comparative gross morphological studies on the os coxae of crested serpent eagle *(Spilornis cheela)* and brown wood owl *(Strix leptogrammica). J Anim Res,* 9 (3): 439-442, 2019. DOI: 10.30954/2277-940X.03.2019.8

26. Sridevi P, Rajalakshmi K, SivaKumar M: Gross morphological and morphometrical studies on the pelvic girdle of emu *(Dromaius novaehollandiae). J Entomol Zool Stud,* 8 (2): 271-274, 2020.

27. Tamilselvan S, Iniyah K, Jayachitra S, Sivagnanam S, Balasundaram K, Lavanya C: Gross anatomy of os coxae of ostrich *(Struthio camellus). Int J Curr Microbiol Appl Sci,* 4 (4): 201-205, 2015.

28. Deka A, Sarma K, Talukdar M: Gross anatomical study on the pelvic girdle of domestic duck *(Anas platyrhynchos domesticus). Theriogenology Insight: An Int J Reprod Anim,* 9 (2): 69-71, 2019. DOI: 10.30954/2277-3371.02.2019.4

29. Deshmukh SK, Karmore SK, Gupta SK, Kodape S, Prakash R: Comparative biometrical studies on the os coxae and synsacrum of peacock and peahen. *Vet Pract,* 17 (1): 41-42, 2016.

30. Mehta S, Guha K, Shalini S, Kumar C: Gross anatomical studies on the os coxae and synsacrum of Japanese quail *(Coturnix coturnix japonica). Indian J Vet Anat,* 26 (2): 126-127, 2014.

31. Musa WI, Muhammad ST: Clinical evaluation and surgical management of some important reproductive problems of intensively raised chickens in Zaria, Nigeria. *Open J Anim Sci,* 5 (3):325, 2015. DOI: 10.4236/ojas.2015.53036

32. Gray RL, Bumgardner MD: Captive propagation and husbandry of reptiles and amphibians. *Special Pub,* 2:95616-1363, 1984.

33. Palanivelrajan M, Premavathy TS, Sankar P, Prathaban S: Non-surgical management of egg (pee wee egg) bound in a silky bird. *Indian Vet J,* 95 (2): 61-62, 2018.

34. Stoessel A, Kilbourne BM, Fischer MS: Morphological integration versus ecological plasticity in the avian pelvic limb skeleton. *J Morphol,* 274, 483-495, 2013. DOI: 10.1002/jmor.20109

35. Anten-Houston MV, Ruta M, Deeming DC: Effects of phylogeny and locomotor style on the allometry of body mass and pelvic dimensions in birds. *J Anat,* 231 (3): 342-358, 2017. DOI: 10.1111/joa.12647

36. Shatkovska OV, Ghazali M, Mytiai IS, Druz N: Size and shape correlation of birds' pelvis and egg: Impact of developmental mode, habitat, and phylogeny. *J Morphol,* 279 (11): 1590-1602, 2018. DOI: 10.1002/jmor.20888

37. Deeming DC: Effects of phylogeny and hatchling maturity on allometric relationships between female body mass and the mass and composition of bird eggs. *Avian Poult Biol Rev,* 18, 21-37, 2007.