مجلـــــة السعيد للعلـــــوم الإنســـانيـــة والتطبيقية
Al - Saeed Journal of Humanities and Applied Sciences
journal@alsaeeduni.net
Vol (6), No(1), January, 2023 المجلد(6)، العدد(1)، 2023م
ISSN: 2616 – 6305 (Print) ISSN: 2790-7554 (Online)

The Skeletal Characteristics of Limb of Two endemic Lizard Species (*Acantocercus adramitanus* and *Chamaeleo calyptratus*) in Yemen

Dr. Yaser H. A. Obady
Dept. of Biology, Faculty of Applied Science, Taiz University and Faculty of Medicine and Health Sciences, Al Saeed University, Taiz, Yemen
Yaserobady52@yahoo.com

تاريخ تسليم البحث 2022/10/28م تاريخ قبوله للنشر 2023/1/2م
https://alsaeeduni.net/colleges/research-and-strategic/2017-03-10-08-03-59

The Skeletal Characteristics of Limb of Two endemic Lizard Species (*Acantocercus adramitanus* and *Chamaeleo calyptratus*) in Yemen

Dr. Yaser H. A. Obady
Dept. of Biology, Faculty of Applied Science, Taiz University and Faculty of Medicine and Health Sciences, Al Saeed University, Taiz, Yemen

Abstract

Lizards have the broadest geographical distribution encompassing a wide range of locomotor habitats. This is reflected in a large morphological diversity of the general body form and of the locomotory apparatus among these animals. So, the present study aimed to clarify the osteological characteristics of the limb skeleton of two endemic species sharing the same environment but differ in microhabitat and mode of their locomotion. Under a dissecting microscope, the fore and hindlimbs of each animal were excised by using iris scissors after narcotizing by doses of anesthetic. The specimens were processed for staining with Alcian blue and alizarin stains to stain the skeletal limbs. In the current study, intra- and interspecific variations were observed in 2 species studied in measurements of limb elements. In *Chamaeleo calyptratus* both the fore- and hind limbs were relatively equal in length. While, the FOL, MAL, TOFL2, TOFL3, TOFL4 and TOFL5 were significantly shorter than the hindlimb in *Acantocercus adramitanus* (t= -5.60, -8.59, -3.84, -6.69, -6.12 and -8.35 respectively *P*= 0.000). A significant pronounced variation in the length of the long bone in lizard studied. Meanwhile, high significant variations were noticeable for metacarpus and metatarsus measurements in *A. adramitanus* ($F_{4,45}$= 88.66, P< 0.0001 and $F_{4,45}$= 32.07, P <0.0001 respectively). Slightly significant variations were observed in metacarpus and metatarsus measurements of *C. calyptratus* ($F_{4,45}$= 3.34, P<0.02 and $F_{4,45}$= 3.42, P<0.02 respectively). Except the centrale, the width of elements composing the wrist and ankle is larger than length in *A. adramitanus*. High significant variations were noticeable in the autopodium of *C. calyptratus*. The radiale and centrale had larger length than width. However, *C. calyptratus* have relatively short ulnare, distal carpus 5 and proximal tarsus. These variations in limb elements of *A. adramitanus* and *C. calyptratus* may be due to the difference in microhabitat.

Keywords: Yemen, Limb, Characteristics.

الخصائص الهيكلية للطرف لنوعين من الزواحف المستوطنة (الوحر الصخري والحرباء المحجبة) في اليمن

د/ ياسر حسن احمد عبادي

قسم البيولوجي- كلية العلوم التطبيقية – جامعة تعز

وكلية الطب والعلوم الصحية – جامعة السعيد – تعز – اليمن

الملخص العربي

تمتلك السحالي انماط حركية متنوعة وتوزيع جغرافي واسع، والذي ينعكس في التنوع الكبير في أشكالها، لذلك تهدف الدراسة الحالية الى توضيح الصفات العظمية للأطراف الأمامية والخلفية لنوعين من البيئة اليمنية يتشاركان نفس البيئة ويختلفان في الموطن ونظام الحركة. وقد اوضحت نتائج البحث وجود اختلافات واضحة احصائيا في القياسات العظمية لكلا النوعين سواء بين النوعين قيد الدراسة او في الصفات العظمية لنفس النوع. وقد لوحظ تساوي قياسات الطرف الأمامي والخلفي في الحرباء المحجبة، بينما يمتلك الوحر الصخري أطراف امامية قصيرة مقارنه بأطرافه الخلفية. وقد ارجع السبب في تباين الصفات العظمية للنوعين لاختلاف الموطن الاقتصادي المستخدم لكل نوع.

الكلمات المفتاحية: اليمن، الطرف، الخصائص.

Introduction

Squamata is one of the largest orders of vertebrates with 11430 recognized species. In Yemen, the reptiles include 110 species of lizards [1]. *Acantocercus adramitanus* (Anderson, 1896) from the family Agamidae, and *Chamaeleo calyptratus* (Dumeril, 1851) from the family Chamaeleonidae are two common species in southwest Arabia, furthermore, In Yemen, *A. adramitanus* is widespread from southwest of Yemen into Dhofar in the east and abundant in the mountains up to 2300 m, it is observed at Al Nabi Shuaib mountain (30 km west of Sana'a). The etymology of this species was related to Hadhramaut governorate [2-5].

Recently, 12 genera and more than 220 species are recognized within the family Chamaeleonidae [1,5-8], with members of this family distributed across Africa into the Middle East, southern Europe, India, and across a few small islands in the Indian Ocean [9]. In Yemen, the veiled or Yemeni Chameleon, *C. calyptratus*, is found in the western mountains, is abundant in the Taiz. It is native to the southwestern Arabian peninsula in western Yemen and southwestern Saudi Arabia. This species has currently been introduced into Hawaii and Florida, where it thrives and appears to be flourishing [3,10-15].

Coordinated changes in anatomical systems are related with the diversity of vertebrates. As the mode of locomotion changes, the loss of innovation would be functionally advantageous and thus favored. However, to determine if this pattern is generalizable, it would be appropriate to investigate the resulting changes and trade-offs that occur during evolutionary reduction and functional loss within a clade that displays a spectrum of changes in a highly functional anatomical complex. Much of what is known about the locomotor structures relates to limb loss and reduction such as in lizards. The increase in the rate of evolutionary change in these situations suggests that the origin of an elongate body likely led not only to relaxed selection for the retention of limbs but also to rapid adaptive selection, favoring both their loss and other associated morphological changes. In these cases, it is expected that both the rate of morphological evolution and the area occupied in phylomorphospace would increase [16-21].

Biologists have long been attracted to locomotor extremes because they provide an especially clear example of which determines the structure-function relationship. The size, shape and action in living organisms are very closely linked together. Furthermore, the limb morphology in tetrapods is closely reflects locomotor performance and ecological characteristics. Many studies have focused on the relationships between morphology, ecology, and behavior. So, movement through the environment is the behavior that most dictates the morphology and physiology of animals. The gait an animal selects depends on the rate of travel; obstructions in the terrain, maneuverability sought, and body size of the animal [22-25].

The connection between an animal's morphology and ecological parameters such as habitat characteristics emphasize the link between phenotype and the environment but are often difficult to explain because the functional consequence of morphological variations is frequently unknown[26].

The movement is important factor during activities of animals such as feeding, social interactions and predator avoidance. So, the locomotion is considered one of the major functions within the ecology of an animal [27]. A number of osteological characteristics related to movement were quantified, including the body size and bone length of the fore- and hindlimbs.

The interspecific variation of modes of locomotion among lizards has been explored by different authors [28-30]. The animals move through heterogeneous physical environments at different speeds and using various modes of locomotion. The lizards have the broadest geographical distribution encompassing a wide range of locomotor habitats, and these animals are an interesting model to study the effects of the variety in locomotor habitat (e.g. climbing, swimming or digging vs running) on the locomotory apparatus. This is reflected in a large morphological diversity of the general body form and of the locomotory apparatus among these animals. In Yemen, the topographical variations perhaps give rise to a wide range of mode of lizard locomotion. So, the present study aimed to clarify the osteological characteristics of the limb skeleton of two endemic species sharing the same environment but differ in microhabitat and mode of their locomotion.

MATERIAL AND METHODS

Twenty samples were taken from adult individuals, 10 *Acantocercus adramitanus* and 10 *Chameleon calyptratus* were caught from Taiz governorate through the period of October 2017- December 2018 in the present investigation at different lengths of snout-ventral length (SVL, 52-125 mm and 90-200 mm respectively). Identification and systematic classification of the specimens were carried out according to Arnold (1980), Obady (1996) and Saleh (1997) [2, 4, 31].

Under a dissecting microscope, the fore and hindlimbs of each animal were excised by using iris scissors after narcotizing by doses of anesthetic. To stain the skeletal limbs, the specimens were processed for staining with Alcian blue and alizarin stains according to Whitaker and Kathleen [32].

All osteometric measurements were taken for every individual to the nearest millimeter on the left side by using dividers and ruler and a calibrated eye-piece graticule by a dissecting microscope and they are diagrammatically represented in Figure 1 with the same numbers mentioned herein. The following osteological measurements were recorded for each specimens:

I- Fore limb measurements:

1- Humerus length: The distance from the proximal surface of the head to the distal articular surface with radio-ulna (HL).
2- Humerus width at proximal head: Maximum width of proximal humerus epiphysis (HW1).
3- Humerus width at distal head: Maximum width of distal humerus epiphysis (HW2).
4- Ulna length: The distance from the proximal articulation surface with the humerus to the distal head of the ulna (UL).
5- Ulna width at proximal head: Maximum width of proximal ulna epiphysis (UW1).
6- Ulna width at distal head: Maximum width of distal ulna epiphysis (UW2).
7- Radius length: The distance from the proximal articulation surface with the humerus to the distal head of the radius (RL).
8- Radius width at proximal head: Maximum width of proximal radius epiphysis (RW1).

9- Radius width at distal head: Maximum width of distal radius epiphysis (RW2).
10- Metacarpal lengths: The distance from the proximal head to the distal head (Mtc1- Mtc5).
11- Phalangeal lengths: The distance from the proximal articular surface to the distal articular surface of each phalanx (ph).
12- Carpus element lengths: Length of each carpus bone (height-dcl).
13- Carpus element widths: The maximum width of each carpus bone (dcw).

II- Hind limb measurements:

The hindlimb measurements were measured as in the forelimb.

Total forelimb length (FOL), hindlimb length (HIL), manus length (MAL), pes (PEL), forelimb digit length (TOFL1-5) and hindlimb digit length (TOHL1-5) are not measured directly from animals because the limbs could not be straightened. These values were calculated: as the sum of the humerus, ulna and manus lengths for the forelimb. As the sum of the carpus, fourth metacarpus and digital fourth lengths for manus length. As the sum of the phalangeal length of each toe for toe lengths 1-5. For long bone hindlimb lengths, pes length and toe lengths 1-5 were measured as in the forelimb.

Statistical analyses:

For elucidating interspecific variations, the osteometric data of the two species considered were statistically analyzed and described by one-way ANOVA and unpaired t-test using SPSS package release 9.0.0 (SPSS, Inc, 1998) and PAST package release 3.25 [33,34].

Results

Fore and hindlimbs are built on same pattern in *A. adramitanus* and *C. calyptratus*, composed of 3 recognized regions. The autopodium, the distal end of the limb, consists of numerous elements composing the wrist and ankle, while the middle limb region is the zegopodium, with 2 bones: ulna and radius of the forearm, tibia and fibula of hindarm. The limb region closest to the body is the stylopodium, with a single element: the humerus of the forelimb and the femur of the hindlimb. The skeleton of the fore-hindlimb of both studied species was calcified.

In *A. adramitanus*, the proximal carpus constitutes of three bones, Trapezium ulnare, the radiale in rectangular shape with concave upper and lower sides and the centrale bone with quadrangular shape. The distal carpaus consists of carpals 3-5 with cone shape with carpal 1 in rectangular shape and carpal 2 in quadrangular shape. The sesamoid elements are the ulnar patella, pisiform, palmar sesamoid and dorsal sesamoid on the last phalanges of each toe (Fig. 2). In the Pes region, the second and fifth distal tarsal are missing. The distal tarsal 1 in triangular shape, distal tarsal 3 in oval shape and distal tarsal 4 with triangular or triskelions shape. The proximal tarsus is a rectangular shape. The sesamoid elements are the Lunula in the knee region and on the last phalanges of each toe. The phalangeal formula is 1-2-3-4-2 and 1-2-3-4-3 of manus and pes respectively (Fig. 3).

In *C. calyptratus*, the carpal elements of the proximal series are almost diamond radiale, semicircular ulnare and wedge centrale bones. Regarding the distal series, only 3 bones are observed, carpal 1 being present in a rectangular shape, the carpals 2+3+4 are fused with a spherical shape and carpal 5 being present in a rectangular shape. The sesamoid elements are missing. The phalangeal formula is 1-2-3-3-2 (Fig. 4). In the tarsus region, the proximal tarsal is in a spherical shape. However, in the distal series, only 3 bones are observed, tarsals 1 and 3 being present with an almost oval shape and spherical shape of tarsal 4. The phalangeal formula is 1-2-3-3-2 (Fig. 5).

The epiphyses of phalanges are calcified in the studied specimens. These epiphyses are not fused with their shafts and are separated by a cartilaginous zone. In *A. adramitanus*, the ulnar patella is located in dense fibrous tissue.

In *C. calyptratus* both the fore- and hind limbs were relatively equal in length. While, the FOL, MAL, TOFL2, TOFL3, TOFL4 and TOFL5 were significantly shorter than the hind limb in *A. adramitanus* (t= -5.60, -8.59, -3.84, -6.69, -6.12 and -8.35 respectively P= 0.000).

There is a significant pronounced variation in the length of long bone in lizard studied (Table 1). The *C. calyptratus* had significantly longer of FOL, CAL, MAL, TOFL1, TOFL2, TOFL3, TOFL4, TOFL5, TAL, TOHL1 and TOHL2 than in *A. adramitanus*. However, *A. adramitanus* was discriminated from *C. calyptratus* in PEL.

In stylopodium, the *C. calyptratus* has HL, HW2 and FW2 longer than in *A. adramitanus*. In addition, the *C. calyptratus* recorded significant largest values in zegopodium of UL, UW1, UW2, RL, RW1, RW2, FIW1 and FIW2.

High significant variations were noticeable for metacarpus and metatarsus measurements in *A. adramitanus* ($F_{4,45}$= 88.66, P < 0.0001 and $F_{4,45}$= 32.07, P <0.0001 respectively). The Mtc3 is the longest of the series that decreases in sequences 3, 4, 2, 1, 5 for metacarpus, while Mtt4 is the longest of the series that decreases in sequences 4, 3, 2, 1 and 5 for metatarsus. Slightly significant variations were observed in metacarpus and metatarsus measurements of *C. calyptratus* ($F_{4,45}$= 3.34, P<0.02 and $F_{4,45}$= 3.42, P<0.02 respectively). The Mtc4 is the longest of the series that decreases in sequences 4, 3, 2, 1 and 5 for metacarpus, while Mtt3 is the longest of the series that decreases in sequences 3, 2, 5, 4 and 1 for metatarsus (Table 2).

Except for the central bone, the width of elements composing the wrist and ankle is larger than the length in *A. adramitanus* (Table 3). High significant variations were noticeable in the autopodium of *C. calyptratus*. The radiale and central bones had larger lengths than width. However, *C. calyptratus* have relatively short ulnare, distal carpus 5 and proximal tarsus.

Table 1: The basic statistics (mean ± SE, minimum and maximum) and t –test of long bone osteometric characters of examined lizard (N=10 for each type).

	Forelimb								
	FOL	CAL	MAL	TOFL1	TOFL2	TOFL3	TOFL4	TOFL5	
A	54.91±2.52	18.51±0.72	1.94±0.16	4.05±0.16	7.05±0.25	9.97±0.44	10.49±0.44	6.53±0.27	
	45.5-73.7	16.05-23.7	1.25-2.75	3.25-5	6-8.75	8.5-13	8.8-13.7	5.5-8.25	
B	77.98±4.75	4.86±0.5	21.78±1.47	7.51±0.64	10.5±0.67	12.37±0.83	12.93±0.79	11.37±0.78	
	57.25-99.53	3-8.5	15.25-30.75	4.95-10	7.25-13.25	8.75-15.75	10-17.25	8-15.5	
t-test	-4.29***	-5.51***	-2.01*	-5.22***	-4.81***	-2.56*	-2.68*	-5.85***	
	Hindlimb								
	HIL	TAL	PEL	TOHL1	TOHL2	TOHL3	TOHL4	TOHL5	
A	79.64±3.62	3.03±0.26	32.24±1.43	4.35±0.23	8.72±0.36	14.83±0.58	15.61±0.71	12.38±0.65	
	65.75-104.75	2.25-5	26.75-41.75	3.5-6	7.25-11.25	12.5-18.75	13.25-20.75	9.75-16.5	
B	75.15±4.83	4.15±0.27	21.45±1.3	8±0.56	11.08±0.79	13.86±0.94	13.8±0.96	12.01±0.87	
	52.75-97.25	2.5-5	14.75-27.25	5.5-11	8-15.	9.25-18.25	9.5-18.75	8.5-16.25	
t-test	0.74	-3.02**	5.59***	-5.98***	-2.71*	0.88	1.52	0.34	
	Humerus			Ulna			Radius		
	HL	HW1	HW2	UL	UW1	UW2	RL	RW1	RW2
A	19.5±1.06	6.38±0.31	5.35±0.46	16.9±0.87	2.79±0.19	2.22±0.13	15±0.52	1.95±0.14	1.5±0.14
	15-27	5-8.25	3.75-8.5	13-23	2.25-4.25	1.7-3	12.-18	1.25-2.6	1-2.15
B	28.7±1.97	6.48±0.54	7.21±0.68	27.5±1.59	4.44±0.42	3.74±0.26	26.5±1.81	3.31±0.38	2.38±0.2
	20-37	3.5-8.5	4.75-10	21-37	2.75-7.5	2.5-5	18-35	1.75-5	1.5-3.25
t-test	-4.12***	-0.17	-2.26*	-5.85***	-3.58**	-5.23***	-6.11***	-3.38**	-3.61**
	Femur			Fibula			Tibia		
	FL	FW1	FW2	FIL	FIW1	FIW2	TIL	TIW1	TIW2
A	25.8±1.29	4.45±0.43	4.4±0.21	21.6±1.14	1.2±0.08	1.62±0.14	21.6±1.14	3.32±0.26	2.74±0.14
	21-35	2.75-7.5	3.5-5.5	18-28	0.75-1.5	0.9-2.5	18-28	2.5-5.5	2-3.5
B	29.9±2.02	5.3±0.36	6.1±0.45	23.8±1.6	4.63±0.34	2.88±0.13	23.6±1.76	2.94±0.56	3.08±0.4
	21-40	3.5-7	4.25-9	17-33	3.5-7	2.5-3.5	16-35	1.1-7.5	1.25-5
t-test	-1.71	-1.51	-3.45**	-1.12	-9.74***	-6.45***	-0.95	0.61	-0.79

***- significant at P≤0.05 **- significant at P≤0.001 ***- significant at P≤0.0001**

A= *A. adramitanus* B= *C. calyptratus*

Table 2: The basic statistics (mean ± SE, minimum and maximum) of metacarpus, metatarsus and phalanges for forelimb and hindlimb osteometric characters of *A. adramitanus* and *C. calyptratus* (N=10 for each type).

	Metacarpus						
	Mtc1	Mtc2	Mtc3	Mtc4	Mtc5		
A	3.87±0.16	5.48±0.11	6.35±0.16	6.09±0.18	2.9±0.17		
	3.25-4.5	5-6.25	5.5-7	5.25-7.25	2.25-4		
B	3.15±0.21	3.41±0.28	3.95±0.28	4±0.31	2.84±0.28		
	2.-4	2-4.5	2.25-5	2.25-5.5	1.75-4.25		
	ToeI	ToeII		ToeIII			
	Ph1	Ph1	Ph2	Ph1	Ph2	Ph3	
A	4.05±0.16	3.02±0.13	4.04±0.14	3.11±0.13	3.09±0.15	3.77±0.17	
	3.25-5	2.5-3.75	3.5-5	2.5-4	2.5-4	3.25-5	
B	7.51±0.64	6.13±0.47	4.37±0.25	5.61±0.46	3.43±0.25	3.33±0.19	
	4.95-10	4.1-8.5	3.15-5.5	3.25-7.5	2.25-4.5	2.45-4	
	ToeIV				ToeV		
	Ph1	Ph2	Ph3	Ph4	Ph1	Ph2	
A	2.57±0.1	2.19±0.09	2.48±0.11	3.25±0.16	2.58±0.12	3.95±0.15	
	2.25-3.25	1.75-2.7	2-3.25	2.75-4.5	2-3.25	3.5-5	
B	5.93±0.47	3.55±0.24	3.45±0.23	-	6.47±0.54	4.9±0.35	
	3.5-8.25	2.5-5	2.75-4.75	-	4.25-9	3.5-6.75	
	Metatarsus						
	Mtt1	Mtt2	Mtt3	Mtt4	Mtt5		
A	7.9±0.69	10.96±0.48	12.58±0.68	13.6±0.98	4.43±0.22		
	2.25-10	9.25-14	9.25-16	10.75-21.25	3.5-6		
B	3.38±0.25	4.13±0.23	4.62±0.23	3.5±0.24	3.96±0.37		
	2.5-5	3-5.	3.5-5.75	2.25-4.5	2.25-5.75		
	ToeI	ToeII		ToeIII			
	Ph1	Ph1	Ph2	Ph1	Ph2	Ph3	
A	4.35±0.23	4.31±0.17	4.41±0.2	5.78±0.2	4.35±0.18	4.7±0.22	
	3.5-6	3.75-5.5	3.5-5.75	5.-7	3.75-5.5	3.75-6.25	
B	8±0.56	6.68±0.51	4.4±0.31	7.03±0.46	3.68±0.25	3.16±0.25	
	5.5-11	4.75-9.25	3.25-6.25	5-9.	2.5-5	1.75-4.5	
	ToeIV				ToeV		
	Ph1	Ph2	Ph3	Ph4	Ph1	Ph2	Ph3
A	4.63±0.27	3.43±0.15	3.4±0.14	4.16±0.18	4.08±0.24	4.05±0.19	4.25±0.23
	3.75-6.5	3-4.5	2.75-4.25	3.5-5.5	3-5.5	3.25-5	3.5-6
B	6.45±0.47	3.85±0.25	3.5±0.26	-	6.93±0.53	5.09±0.34	
	4.5-9	2.5-5	2.5-4.75	-	4.75-9.5	3.75-6.75	

A= ***A. adramitanus*** **B=** ***C. calyptratus***

Table 3: The basic statistics (mean ± SE, minimum and maximum) and t –test of carpus and tarsus osteometric characters of *A. adramitanus* and *C. calyptratus* (N=10 for each type).

	Proximal carpus									
	rel	**rew**	**ull**	**ulw**	**cl**	**cw**				
A	0.69±0.05	1.62±0.12	0.83±0.03	1.86±0.08	0.38±0.07	0.45±0.04				
	0.5-1	0.9-2	0.75-1	1.5-2.5	0.2-0.9	0.25-0.6				
t -test	-7.22***		-11.56***		-0.94					
B	2.72±0.25	1.64±0.16	1.37±0.17	3.39±0.35	1.85±0.18	0.68±0.08				
	0.85-3.5	1-2.75	0.45-2	1.1-5	0.75-2.5	0.35-1.1				
t -test	3.68**		-5.1***		5.86***					
	Distal carpus									
	dcll	**dc1w**	**dc2l**	**dc2w**	**dc3l**	**dc3w**	**dc4l**	**dc4w**	**dc5l**	**dc5w**
A	0.46±0.08	0.71±0.12	0.46±0.03	0.67±0.06	0.53±0.03	0.97±0.11	0.79±0.07	1.23±0.11	0.95±0.07	1.17±0.06
	0.2-1	0.35-1.5	0.3-0.65	0.45-1	0.4-0.75	0.5-1.6	0.5-1.35	0.75-2	0.65-1.25	0.85-1.5
t -test	-1.75*		-3.2**		-3.82**		-3.41**		-2.49*	
B	0.99±0.21	1.16±0.21	3.21±0.29	3.58±0.22 #					0.82±0.1	1.51±0.13
	0.45-2.3	0.5-2.25	1.65-4.5	2.75-4.6					0.35-1.5	0.85-2
t -test	-0.58		-1.01						-4.17***	
	Proximal tarsus		**Distal tarsus**							
	Ptl	**Ptw**	**dt1l**	**dt1w**	**dt3l**	**dt3w**	**dt4l**	**dt4w**		
A	1.9±0.12	4.35±0.27	0.48±0.04	0.81±0.12	0.95±0.1	1.39±0.11	1.76±0.13	2.36±0.14		
	1.25-2.25	3.5-6.5	0.35-0.75	0.55-1.75	0.6-1.5	0.75-2	1.1-2.5	2-3.25		
t -test	-8.39**		-2.68*		-2.94*		-3.14*			
B	2.66±0.21	3.9±0.26	0.3±0.13	0.47±0.19	0.93±0.12	0.87±0.18	2.48±0.24	2.78±0.23		
	1.75-3.75	2.5-5	0.5-1	1-1.35	0.5-1.5	0.45-1.75	1.75-4	2-4.25		
t -test	-3.77**		-0.71		0.28		-0.89			

#- distal tarsus 2+3+4 *- significant at P≤0.05 **- significant at P≤0.001 *- significant at P≤0.0001, A= *A. adramitanus* B= *C. c. calyptratus*.**

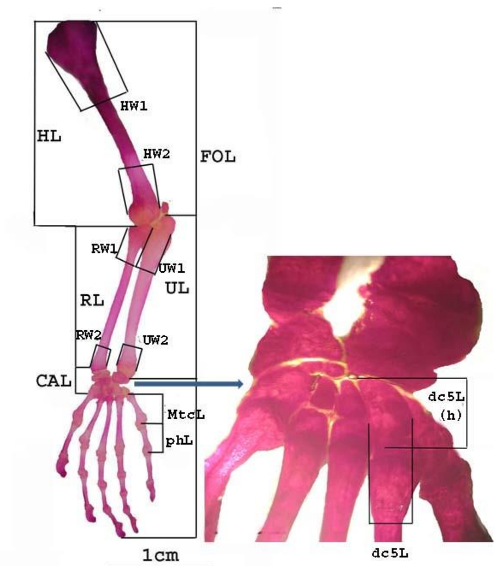

Fig. 1: Illustration of the osteometric measurements taken on the forelimb of *A adramitanus* as representative of the two species studied. The bone measurements were according to Fontanarrosa and Abdala [41] and Obady [45].

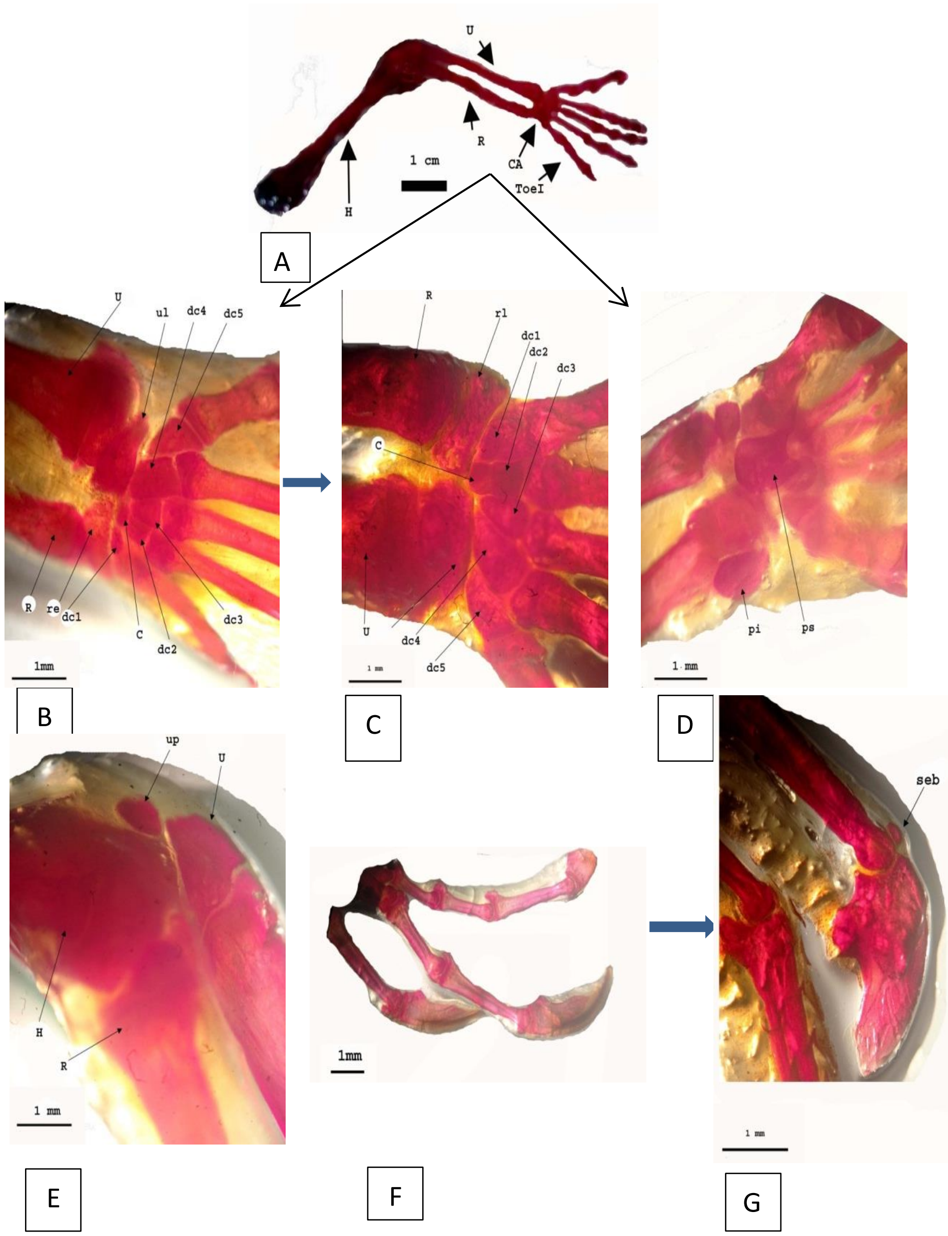

Fig. 2: Photographic illustration of the forelimb elements of *A. adramitanus* (The thick arrows indicate the magnification). A: Whole mount (dorsal view), B: Left wrist joint (dorsal view), C: Right wrist joint (dorsal view), D: Wrist joint (ventral view), E: Elbow joint (dorsal view) and F and G: Toes (lateral view).

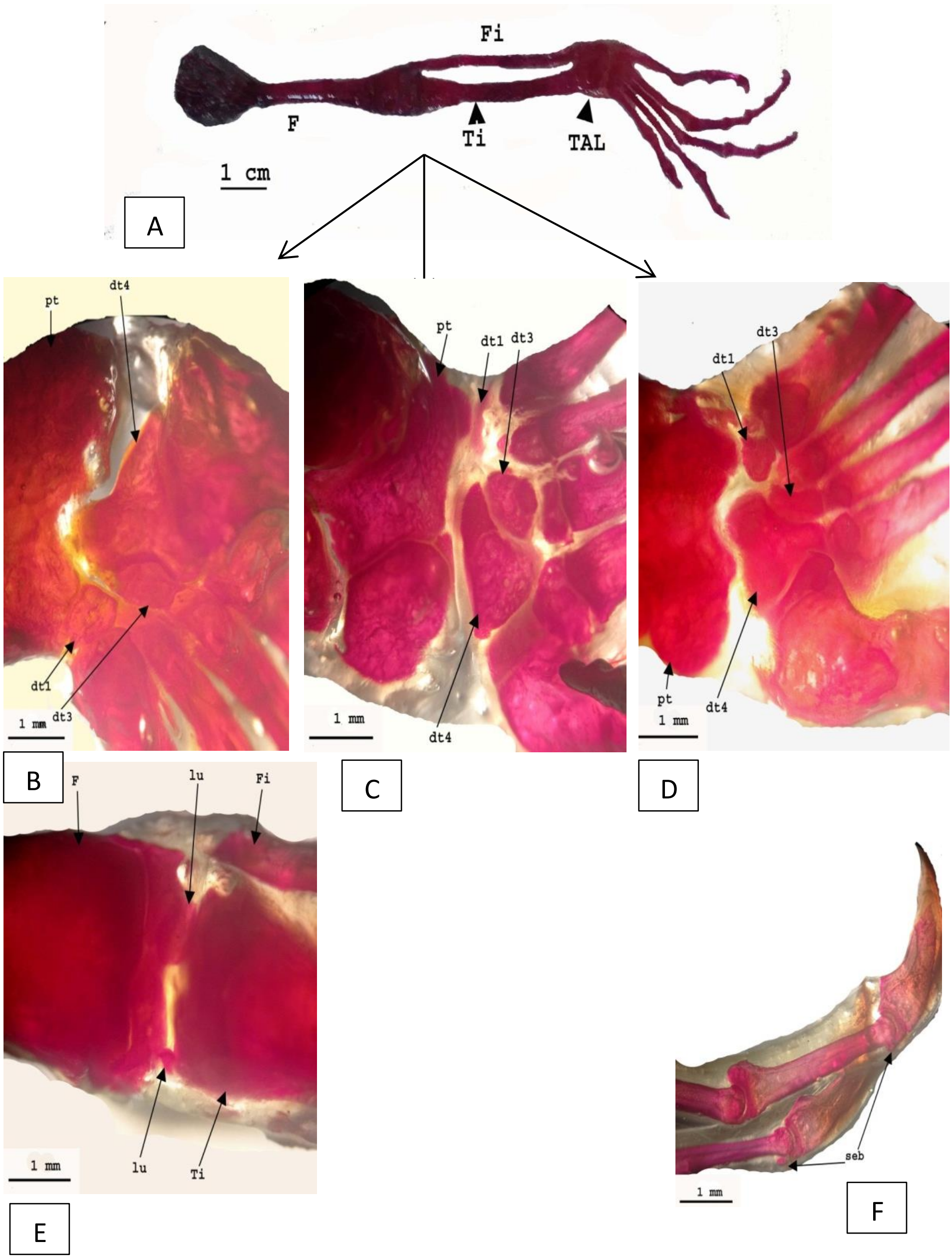

Fig. 3: Photographic illustration of the hindlimb elements of *A. adramitanus* (The arrows indicate the magnification). A: Left whole mount (dorsal view), B: Right wrist joint (ventral view), C: Right wrist joint (dorsal view), D: Left wrist joint (ventral view), E: Left elbow joint (dorsal view) and F: Toes (lateral view)

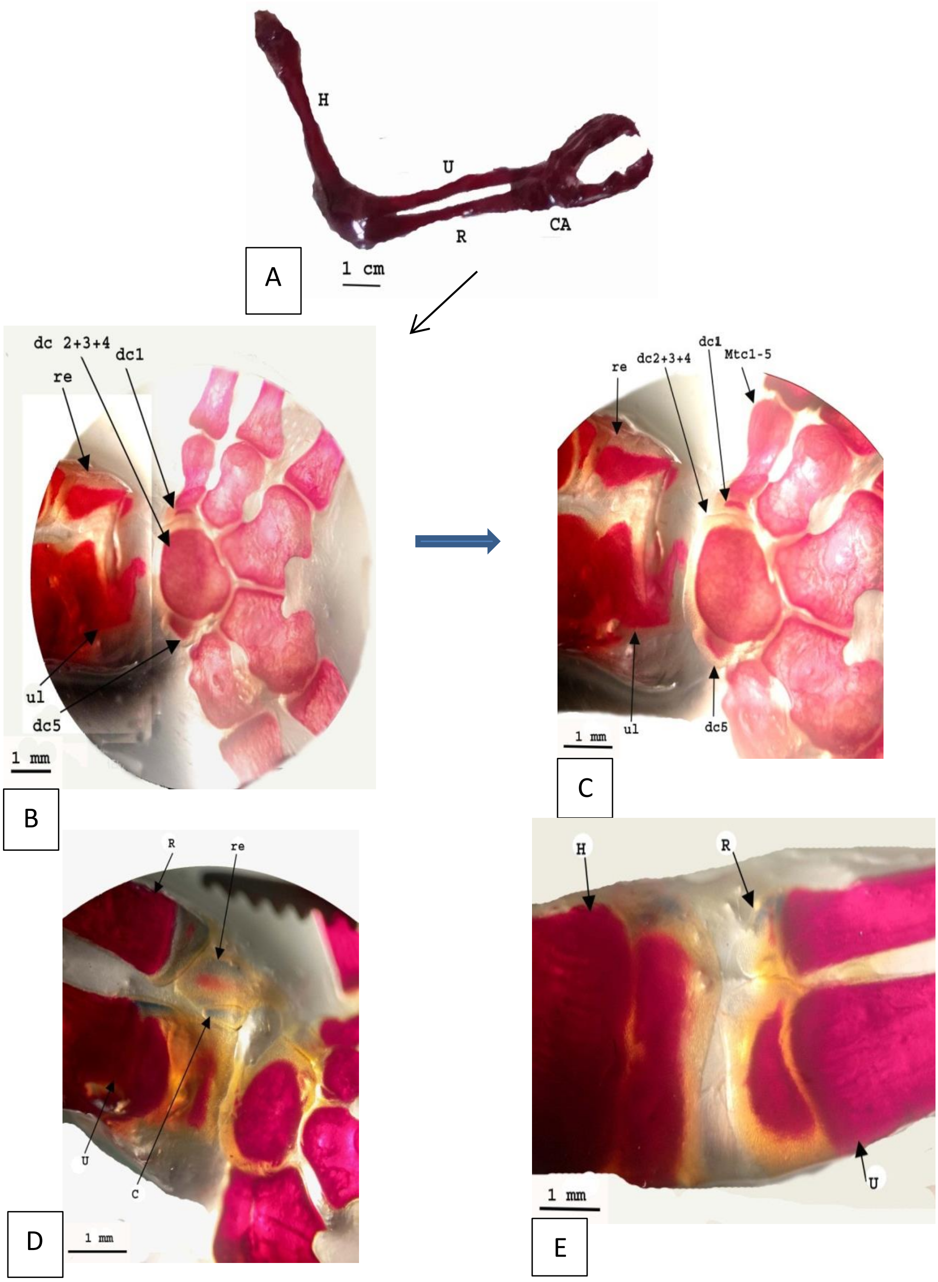

Fig. 4: Photographic illustration of the forelimb elements of *C. calyptratus* (The arrows indicate the magnification). A: Left whole mount (dorsal view), B: Right wrist joint (dorsal view), C: Right wrist joint (dorsal view), D: Right wrist joint (dorsal view) and E: Right elbow joint (dorsal view).

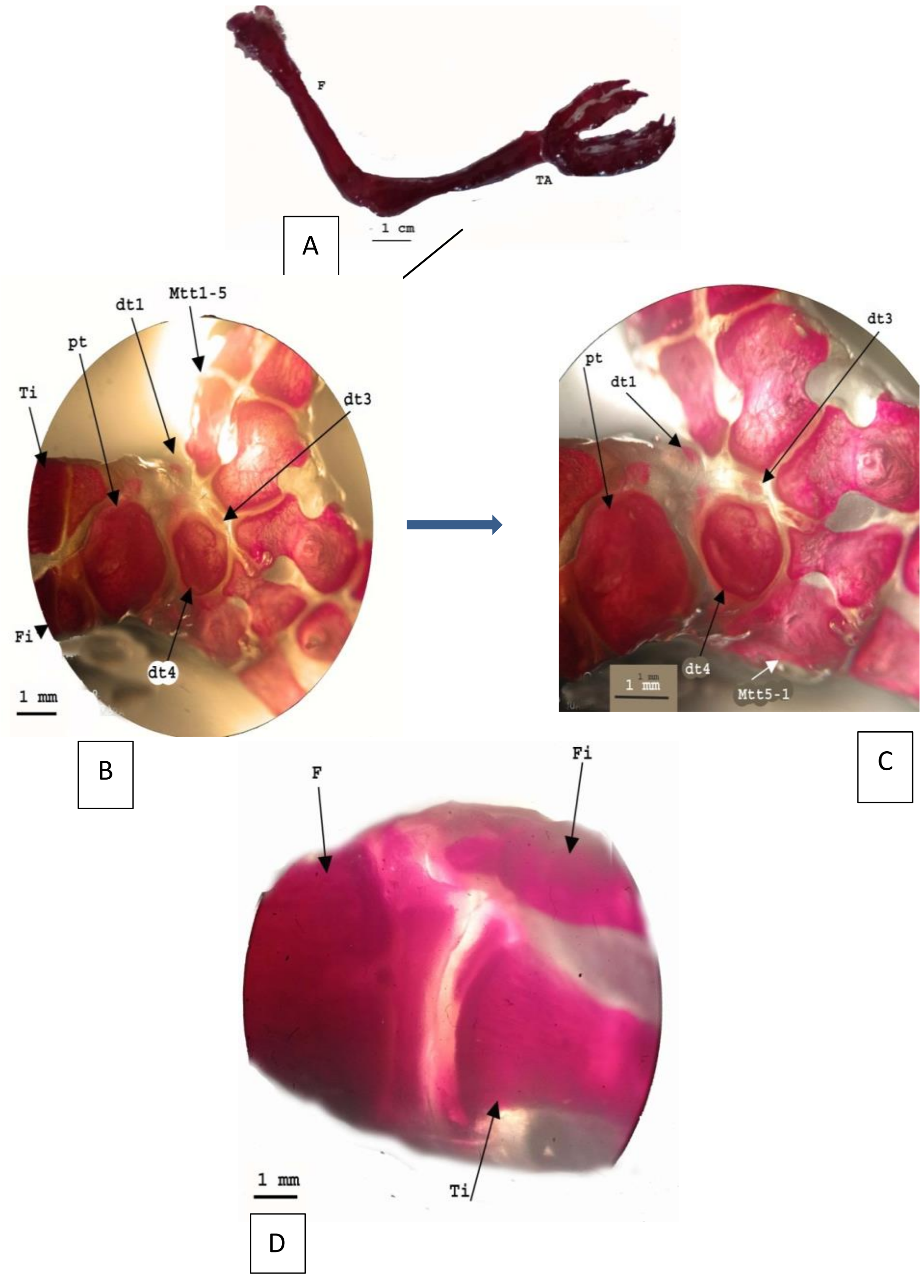

Fig. 5: Photographic illustration of the hindlimb elements of *C. calyptratus* (The arrows indicate the magnification). A: Left whole mount (dorsal view), B: Right wrist joint (dorsal view), C: Right wrist joint (dorsal view) and D: Right elbow joint (dorsal view).

Discussion

Yemen is characterized by the high biodiversity in the Arabian Peninsula which contains different types of microhabitats, and different morphological features Obady [4], however, the studied species have been a model of study in ecomorphology which *Chameleon calyptratus* a strictly arboreal species was compared with *Acantocercus adramitanus* that inhabits the lower strata of vegetation.

The limb skeleton was investigated as a trail to find out structural and functional differences between *A. adramitanus* and *C. calyptratus*. The modification of basic pattern of limb skeleton occur from group to group in adult limbs include fusion or loss of its fundamental elements, elongation of existing elements and the occasional appearance of new skeletal components. These variations can be back to developmental modifications within the underlying embryonic pattern [24].

Tetrapod limbs are all built on the same pattern, composed of three recognized regions: stylopodium, zeugopodium and autopodium. The most striking differences in the skeleton are at distal ends, autopodium, of the appendages [24,35].

Mohammed [36] reported the homology of the carpus and tarsus in several lizards. The present study showed that the lizard investigated has a great similarity in the osteology of the limb skeletal. However, there are interspecific differences in the number, measures and fusion of some elements. In the present 2 species studied, the limb elements are generally similar to that described by Stephenson and Stephenson [37] in *Naultinus elegans*, *Hoplodactylus duvaucelii* and *Hoplodactylus pacificus*, El-Wetery [38] in Agamidae and Chamaeleontidae, Lima *et al.* [39] in *Caiman yacare*, Yildirim *et al.* [40]) in *Eumeces schneideri barani*, *Eumeces schneideri princeps* and *Eumeces schneideri pavimentatus*, Fontanarrosa and Abdala [41], in several Squamata, Yıldırım *et al.* [42] in *Ablepharus kitaibelii* and Ríos-Orjuela *et al.* [43] in *Anolis heterodermus* and *Anolis tolimensis* and Ali *et al.* [44] in *Acanthodactylus boskianus* and *Ptyodactylus guttatus.*

The reduction or fusion of the carpal and tarsal elements is recorded for current lizards. The ulnare, radiale and centrale bones were recorded in the forelimbs of *A. adramitanus* and *C. calyptratus*. In *A. adramitanus*, the distal carpaus consists of 5 carpals, but the fusion of carpals 2, 3 and 4 were identified in the forelimb of *C. calyptratus*. In the Pes region, the second and fifth distal tarsal are missing *A. adramitanus.* In *C. calyptratus*, only tarsals 1, 3 and 4 being present. On the other hand, there is variability in the presence or absence of the sesamoid elements. The sesamoid elements are the ulnar patella, pisiform, palmar, Lunula and dorsal sesamoid on last phalanges of each toe. However, The sesamoid elements are missing in *C. calyptratus*. These results have disagreement and concord faces with those recorded by Obady [45], El-Bakry *et al.* [46] and Molnar *et al.* [47].

The phalange formula is found in species of the *A. adramitanus* 1-2-3-4-2/1-2-3-4-3.On the other hand, the phalange formula of *C. calyptratus* is 1-2-3-3-2/1-2-3-3-2.

The biomechanical theory, predict that limb proportions should differ between animals with variety in lifestyles. Ground-dwellers should have relatively long, with high tibia: femur ratios, and relatively short forelimbs. Climbers should have relatively short limbs, with low tibia: femur ratios, and equally long hind and forelimbs [26, 44, 48].

A wide range of the relation between the morpho- osteological measurements and locomotors habitats maybe described by several authors [25,48-56].

Fontanarrosa and Abdala [41] suggested that the morphological distinction between graspers and non-graspers is demonstrating the existence of ranges along the morphological continuum within which a new ability is generated. These results support the hypothesis of the nested origin of grasping abilities within arboreality. Thus, the manifestation of grasping abilities as a response to locomotive selective pressure in the context of narrow-branch eco-spaces could also enable other grasping-dependent biological roles, such as prey handling.

In current study, intra- and interspecific variations were observed in the two studied species in measurements of limb elements. In *C. calyptratus* both the fore- and hind limbs were relatively equal in length. While, the FOL, MAL, TOFL2, TOFL3, TOFL4 and TOFL5 were significantly shorter than the hind limb in *A. adramitanus*.

A significant pronounced variation in the length of the long bone in the lizard studied. Meanwhile, high significant variations were noticeable for metacarpus and metatarsus measurements in *A. adramitanus*. Slightly significant variations were observed in the metacarpus and metatarsus measurements of *C. calyptratus*.

Except for the central bone, the width of elements composing the wrist and ankle is larger than the length in *A. adramitanus*. High significant variations were noticeable in the autopodium of *C. calyptratus*. The radiale and centrale bones had larger lengths than width. However, *C. calyptratus* have relatively short ulnare, distal carpus 5 and proximal tarsus. These variations in limb elements of *A. adramitanus* and *C. calyptratus* may be due to the difference in microhabitat.

Conclusion

Acantocercus adramitanus and *Chamaeleo calyptratus* are two common species in Yemen. These two species differ in their limb skeleton and form and these variations may be due to the difference in microhabitat and lifestyles.

References

[1] P. Uetz, P. Freed, and J. Hošek, ″The Reptile Database,″ http://www.reptile-database.org, accessed, (Eds.). 2022.

[2] E.N. Arnold, ″The Reptiles and Amphibians of Dhofar, Southern Arabia,″ *J. Oman Stud. Spec. Rep., 2 pp: 173-332*, 1980.

[3] J.P. Fritz and F. Schütte, ″Agamen aus der Arabischen Republik Jemen″ *Bonn. zool. Beitr., 39(2/3)pp:103-112.* 1988.

[4] Obady, N.A. ″Yemen Animals. Part 2: The amphibian and the reptiles. Obady center for studies and publishing″ (In Arabic). 1996.

[5] F. Glaw, O. Hawlitschek and Ruthensteiner, B. ″A new genus name for an ancient Malagasy chameleon clade and a PDF-embedded 3D model of its skeleton″ *Salamandra, 49: 237–238. 2013*.

[6] K.A. Tolley, T.M. Townsend and M. Vences, ″Large-scale phylogeny of chameleons suggests African origins and Eocene diversification″ *Proc. R Soc., B 280: 20130184. 2013*.

[7] K.A. Tolley and A. Herrel, ″The Biology of Chameleons″ *University of California Press, Berkeley, 2014.*

[8] D. Eshar, R. Lapid and V. Head, ″Transilluminated Jugular Blood Sampling in the Common Chameleon (Chamaeleo chamaeleon)″ *J. of Herpetological Medicine and Surgery, 28(1-2): 1-4. 2018.*

[9] J.R. Macey, J.V. Kuehl, A. Larson, M.D. Robinson, I.H.Uĝurtaş, N.B. Ananjeva, H. Rahman, H.I. Javed, R.M. Osman and A. Doumma ″Socotra Island, the forgotten fragment of Gondwana: Unmasking chameleon lizard history with complete mitochondrial genomic data″ *Mol. Phylogenet Evol., 49: 1015–1018. 2008.*

[10] D. Hillenius, and J. Gasperetti, ″The reptiles of Saudi Arabia: The chameleons of Saudi Arabia″ *Fauna Saudi Arabia 6: 513–527, Basle & Jeddah. 1984.*

[11] J.P. Fritz, and F. Schütte, ″Zur Biologie jemenitischer Chamaeleo calyptratus Üumeril & Üumeril, 1851 mit einigen Anmerkungen zum systematischen Status (Sauria: Chamaeleonidae)″ *Salamandra, 23(1):17-25, 1987.*

[12] S.J. Stahl, ″Captive Management, Breeding, and Common Medical Problems of The Veiled Chameleon (*Chamaeleo calyptratus*)″ *Proceedings Association of Reptilian and Amphibian Veterinarians,1997.*

[13] C. Tilbury, ″Chameleons of Africa, an Atlas including the chameleons of Europe, the Middle East and Asia″ *Edition Chimaira/Serpent's Tale NHBD, 2010*.

[14] Jr.R.E. Diaz, C.V. Anderson, P.D. Baumann, R. Kupronis, D. Jewell, C. Piraquive, J. Kupronis, K. Winter, F. Bertocchini, and P.A. Trainor, ″The Veiled Chameleon (Chamaeleo calyptratus Duméril and Duméril 1851): A Model for Studying Reptile Body Plan Development and Evolution″. *Cold Spring Harbor Laboratory Press. 2015.*

[15] K.L. Krysko, K.M. Enge, and F.W. King, ″The veiled chameleon, Chamaeleo calyptratus Duméril and Bibron 1851 (Sauria: Chamaeleonidae): A new exotic species in Florida″. *Florida Scient, 67: 249–253*, (2004).

[16] L. Bejder and B.K. Hall, ″Limbs in whales and limblessness in other vertebrates: Mechanisms of evolutionary and developmental transformation and loss″. *Evol Dev 4(6):445–458. 2002.*

[17] J.J. Wiens and J.L. Slingluff ″How lizards turn into snakes: A phylogenetic analysis of body-form evolution in anguid lizards″ *Evolution 55(11)pp:2303–2318. 2001*.

[18] R. Lande ″Evolutionary mechanisms of limb loss in tetrapods″ *Evolution 32(1)pp: 73–92, 1978.*

[19] C. Gans ″Tetrapod limblessness: Evolution and functional corollaries″ *Am Zool 15(2):455–467*, 1975.

[20] A. Skinner, M.S.Y. Lee and M.N. Hutchinson, ″Rapid and repeated limb loss in a clade of scincid lizards″ *BMC Evol Biol*, *(8)pp:310. 2008.*

[21] B. Sidlauskas, ″Continuous and arrested morphological diversification in sister clades of characiform fishes: A phylomorphospace approach″ *Evolution 62(12)pp: 3135–3156, 2008.*

[22] M. Haire ″Size, Shape and Function in Industrial Organizations″ *Society for Applied Anthropology.pp:17-22, 2012*.

[23] M.H. Dickinson, C.T. Farley, R.J. Full, M.A.R. Koehl, R. Kram and S. Lehman, ″How animals move: An integrative view″ *Sci., (288)pp:100-106, 2000.*

[24] K.V. Kardong, ″Vertebrates: Comparative Anatomy, Function, Evolution, 3rd Edition″ *McGraw-Hill, Inc. New York, pp:317-357. 2002.*

[25] W. Anzai, A. Omura, A.C. Diaz, M. Kawata and H. Endo ″Functional Morphology and Comparative Anatomy of Appendicular Musculature in Cuban Anolis Lizards with Different Locomotor Habits″ *ZOOL. SCIE.31: 454–463,2014.*

[26] M.H. Abou Egla, F.I. El-Sayad and Y.H.A. Obady, ″The Relationship Between The Limb Variation and Habitat use in Lizard Families: Agamidae, Gekkonidae, Scincidae, and Chamaeleontidae″ *Egypt. J. Exp. Biol. (Zool.), 4: 243–256, 2008*.

[27] F. Brana, ″Morphological correlates of burst speed and field movement patterns: the behavioural adjustment of locomotion in wall lizards (*Podarcis muralis*)″ *Biol. J. Linn. Soc. (80)pp: 135-146. 2003*.

[28] S. Nauwelaerts and P. Aerts, ″Two distinct gait types in swimming frogs″ *J. Zool. 258: 183-188.* 2002.

[29] J. W. Glasheen and T. A. McMahon ″Size-dependence of water-running ability in basilisk lizards (*Basiliscus basiliscus*)″ *J. of Exp. Biol., (199)pp: 2611–2618, 1996.*

[30] J.B. Losos, K.I. Warheit and T.W. Schoener, ″Adaptive differentiation following experimental island colonization in Anolis lizards″ Nature, 387: 70-73.1997

[31] M.A. Saleh, ″Amphibians and Reptiles of Egypt″ *Publication of National Biodiversity Unit, Egypt. 1997.*

[32] J. Whitaker and M.D. Kathleen, ″Double staining technique for rat foetus skeletons in teratological studies″ Lab. Animal, 13: 309-310. 1979.

[33] Spss, release 9.0.0, Inc. ″Statistica for windows, standard version″1998.

[34] Ø. Hammer, D.A.T. Harper and P.D. Ryan, ″PAST: Paleontological Statistics software package for education and data analysis″ Palaeontologia Electronica 4(1):9, 2001.

[35] G.C. Kent and L. Miller ″Comparative anatomy of the vertebrate″ 8th Edition. *McGraw-Hill, Inc. New York, pp:195-227.* 1997.

[36] M.B.H. Mohammed ″Carpus and tarsus patterns in some arbian lizards (Reptilia: Agamidae, Lacertidae, Scincidae)″ *Folia Morphologia, 36(2)pp: 201-207,* 1989.

[37] N.G. Stephenson and E.M. Stephenson ″The osteology of the New Zealand Geckos and its Bearing on Their Morphological Status″ *Transactions of the Royal Society of New Zealand Vol. 84(2), pp.341-358.* 1955.

[38] H.M. El-Watere ″Comparative Anatomical Studies on Some Organs in Reptiles″ *Ph.D. Thesis, Mansours University. Egypt. 1992.*

[39] FC. Lima, LG. Vieira, A.L.Q. Santos, H.C. Pereira, S.B.S. De Simone, L.Q.L. Hirano, MF. Romão, J.M.M. Silva and M.E. Coutinho, ″Skeletogenesis of the pectoral girdle and forelimbs in embryos of *Caiman yacare* (Daudin, 1802) (Crocodylia, Alligatoridae)″, *J. Morphol. Sci., 2011, vol. 28, no.1, p.4-10, 2011*.

[40] E. Yildirim, Y. Kumlutaş and Ç. Ilgaz ″A Preliminary Study of Comparative Osteology of the Scincid Lizard Eumeces schneideri (Daudin, 1802) (Squamata: Scincidae) Subspecies in Anatolia″ *J. of Anatolian Natural Sciences 6(1)pp: 34-43. 2015.*

[41] G. Fontanarrosa and V. Abdala ″Bone indicators of grasping hands in lizards″, *Peer, J, pp:1-28,* 2016.

[42] E. Yildirim, Y. Kumlutaş, K. Candan and Ç. Ilgaz ″Comparative skeletal osteology of three species of Scincid lizards (Genus: Ablepharus) from Turkey″, *Vertebrate Zoology 67(2) pp:251-259,* 2017.

[43] J.C. Ríos-Orjuela, J.S. Camacho-Bastidas, A. Jerez ″Appendicular Morphology and Locomotor Performance of two Morphotypes of Continental Anoles: *Anolis heterodermus* and *Anolis tolimensis*″, https://doi.org/10.1101/743807. 2019.

[44] G.GR. Ali, A.M. Fatma, A.S. Samy, A.E. Boshra, A.A. El-Dahshan, I.G. Doaa ″Comparative Functional Analysis of the Anatomy of the appendicular skeleton in two reptilian species″, *Egy.J. of Hosp. Med. Vol. 71 (7), pp: 7274-7287, 2018.*

[45] Y.H.A. Obady ″The relation between foot anatomy in some amniota and chordate diversity in locomotion pattern″, *Ph.D. thesis. Mansoura. Egypt. 2008.*

[46] A.M. El-Bakry, A.M. Abdeen and R.E. Abo-Eleneen ″Comparative study of the osteology and locomotion of some reptilian species″, *International Journal Of Biology and Biological Sciences Vol. 2(3), pp. 040-058.* 2013.

[47] J.L. Molnar, Jr.R.E. Diaz, T. Skorka, G. Dagliyan and R. Diogo ″Comparative musculoskeletal anatomy of chameleon limbs, with

implications for the evolution of arboreal locomotion in lizards and for teratology″, *J. of Morphology pp:1-21*. 2017.

[48] A. Zaaf and R. Van Damme ″Limb proportion in climbing and ground-dowelling geckos (Lepidosauria, Gekkonidae): a phylogenetically informed analysis″, *Zoomorphology, 121:45-53. 2001*.

[49] L.J. Vitt, JP. Caldwell, P.A. Zani and T.A. Titus ″The role of habitat shift in the evolution of lizard morphology: evidence from tropical Tropidurus″, *Proc. Nat. Acad. Sci. USA, 94: 3828-3832. 1997*

[50] B. Vanhooydonck and R. Van Damme ″Evolutionary relationships between body shape and habitat use in lacertid lizards″, *Evol. Ecol. Res., 1: 785-805*. 1999.

[51] B. Vanhooydonck, R. Van Damme and P. Aerts ″Ecomorphological correlates of habitatpartitioning in Corsican lacertid lizards″, *Funct. Ecol., 14: 358-368. 2000.*

[52] A. Herrel, JJ. Meyers and B. Vanhooydonck ″Correlations between habitat use and body shape in a phrynosomatid lizard (*Urosaurus ornatus*): a population-level analysis″, *Biol. J. Linn. Soc., 74: 305-314. 2001*.

[53] A. Herrel, JJ. Meyers and B. Vanhooydonck, ″Relations between microhabitat use and limb shape in phrynosomatid lizards″, *Biol. J. Linn. Soc., 77pp: 749-763*. 2002

[54] T. Kohlsdorf, TJr. Garland and C.A. Navas ″Limb and tail lengths in relation to substrate usage in Tropidurus lizards″, *J. Morph., 248:151-164. 2001*.

[55] R. Bickel and JB. Losos ″Patterns of morphological variation and correlates of habitat use in Chameleons″, *Biol. J. Linn. Soc., 76: 91–103. 2002.*

[56] DJ. Irschick, B. Vanhooydonck, A. Herrel and J. Meyers,″Intraspecific correlations among morphology, performance and habitat use within a green anole lizard (*Anolis carolinensis*) population″, *Biol. J. Linn. Soc., 85pp: 211–221. 2005*.