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MORPHOMETRIC ANALYSIS OF GERBILLUS ANDERSONI, G. CAMPESTRIS AND G. AMOENUS FROM EGYPT

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ABSTRACT

Despite a significant number of studies on the taxonomy of small mammals, very little of this work has been conducted on species in Egypt. External, cranial and dental morphometric analysis of the closely related Gerbillus andersoni, G. campestris and G. amoenus from different ecogeographical regions of Egypt were studied. Statistical analyses of cranial and dental variability allowed us to discriminate three morphological groups which are congruent with the three clusters suggested by previous morphological studies. Higher similarity is observed between G. andersoni populations in the Sinai and Western Mediterranean Coastal Desert despite the fact that they are separated from each other by about 200 km of the Nile Delta. Cluster and principal component analysis, show higher degree of divergence between the subgenus Dipodillus and the other two subgenera Gerbillus and Hendecapleura. This fact suggests that the morphometric differences observed among species within the genus Gerbillus are not mainly related to its phylogeny.

Key Words: Gerbillus, Principle Component Analysis, Morphometric Measurements, Skull, Egypt

INTRODUCTION

The majority of biosystematics studies of Gerbillus populations of the Egypt has been based on morphological criteria, biometrical data (Osborn and Helmy, 1980) and Karyological studies (Wassif et al., 1969).

The genus Gerbillus Desmarest, 1804 is one of the most diversified groups of rodents inhabiting semiarid and arid areas. Musser and Carleton (2005) reported that genus Gerbillus has never been comprehensively revised and its taxonomy is still holding a number of controversies. In fact, whether this genus is holding subgenera or is good to split off into several genera is still debated. Since its early description, three different subgenera, Gerbillus, Dipodillus and Hendecapleura were created for the genus Gerbillus. The subgenus Gerbillus is characterized by the presence of well-developed auditory bullae, of which the posterior parts reach or even exceed the level of the occipital bone, a maximum number of five metatarsal tubercles, one carpal tubercle, and the presence of opposite cusps in the first upper molar and haired hind feet. The latter is bare in the species of the subgenus Hendecapleura which share some of the other characteristics of the subgenus Gerbillus (e.g. the well-developed auditory bullae) (Ellerman, 1940).

On the other hand, the subgenus Dipodillus shows a mediocre development of the auditory bullae, a higher number of metatarsal tubercles (six), a first upper molar with alternate cusps and hairless plantar surfaces. Even though these three taxa were mostly accepted by most of authors, there was no general agreement about the taxonomic rank to assign to them, in particular, regarding the Dipodillus species. In fact, this taxon has been regarded as a subgenus (Ellerman, 1940; Musser and Carleton, 1993) or as a genus (Osborn and Helmy, 1980; Qumsiyeh and Schlitter, 1991; Pavlinov, 2001). However, Lay (1983) studying the most important characters used to separate these subgenus, recognized only one genus Gerbillus.

Mitochondrial DNA analysis (Abiadh, 2010a; Ndiaye, 2012; 2016) confirmed the subdivision into three distinct taxa as previously identified based on morphology (Abiadh et al., 2010b) and revealed that the elevation of Dipodillus to a genus rank will make Gerbillus a paraphyletic genus. Based on this analysis, it was concluded that the three taxa Dipodillus, Gerbillus and Hendecapleura must be considered as three distinct subgenera belonging to a unique monophyletic genus (Abiadh et al., 2010a).

Based on morphometric measurements, the present study contributes to the taxonomy and distribution of three species of the genus Gerbillus in Egypt. G. andersoni, belonging to the subgenus Gerbillus and G. campestris belonging to the subgenus Dipodillus, and G. amoenus belonging to the subgenus Hendecapleura. Confirmation of species status is based on morphologic, cranial and dental characters.

MATERIALS AND METHODS

The Study Area

The study area were Siwa Oasis, El Faiyum Depression (FD), Western Mediterranean coastal desert (WMCD), Wadi el Natroun and the Delta Mediterranean coastal desert (DMCD) (Fig. 1). Suitable localities were selected at each of these areas for trapping. Folding, Sherman live traps baited with peanut butter and bread were used. The traps were placed near burrows or in foraging areas and left open late afternoon until the following sunrise and checked approximately every three hours. Trapping was conducted for two to three night at each trapping locality, or until specimens were obtained. Captured animals were kept live and taken to the laboratory for examination and processing. Taxonomic identification of the collected animals was based on keys based on external and skeletal characters as given by Osborn and Helmy (1980) and Harrison and Bates (1991). The animals were sacrificed, then the skin and skull were prepared and deposited at Al-Azhar University Zoological Collection (AUZC), Faculty of Science, Al Azhar University, Cairo, Egypt.

Material Examined

A sample of 59 specimens of both sexes were examind. The sample consisted of 30 already available at the AUZC and 29 collected during the cource of this study. These represent material previously identified as 3 different Gerbillus species from different areas of Egypt. Table 1 lists specimens examined in this study.

Morphometric Characteristics

External Measurements

External measurements of freshly killed animals were taken using standard, millimeter ruler and caliper as needed. The following external measurements: HBL – length of head and body, TL – Tail length, EL – Ear Length, HFL – Hind Foot Length, and BM – Body Mass. Similar measurements of animals in the AUZC collections were obtained from the collection database.

Cranial and Dental Measurements

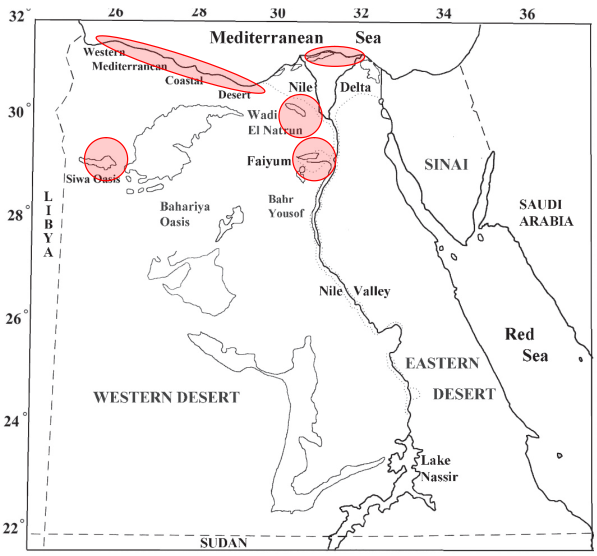

Fig. 1. Map of Egypt showing collection localities of the study animals

Table 1. List of specimens examined during this study with locality, numbers of specimens and geographical coordinates

Species	Locality	No. of collected specimens	No. of AUZC specimens	Coordinates
G. amoenus	Kom O' Shim, El Faiyum	6	-	29° 34′ N 30° 54′ E
	Wadi el Natroun, El Beheira	4	-	30° 23′ N 30° 22′ E
G. andersoni	Baltim, Kafr El Sheikh	8	8	31° 34′ N 31° 13′ E
	Dabaa, Matruh	5	16	30° 59′ N 28° 27′ E
	Bir el Abd, North Sinai	-	6	31° 03′ N 32° 50′ E
D. campestris	Siwa Oasis, Matruh	6	-	29°14′ N 25°31′ E

Cranial and dental measurements were taken using 0-150 mm sliding caliper. Figure 2 shows a graphic definition of measurements in G. andersoni skull.

Statistical Analysis

Principle component analysis (PCA) was conducted using R statistical software program. We examined the differences in each morphological measurement between sexes with F- test (One-way ANOVA) before using them in PCA.

Statistical analysis of the obtained data was done using SPSS (statistical package for social sciences) computer software package, version 20 for One-way ANOVA (analysis of variance) according to Levesque (2007).

RESULTS

A comparison between identified G. andersoni, G. amoenus and G. campestris populations from different ecogeographical areas based on 27 absolute morphological, morphometric characters and 72 ratios was taken. Cranial and dental measurements and ratios show some significant differences between the six studied populations (Table 2).

Comparing these populations based on all morphological characters, using cluster analysis shows that the six sampled populations are clustered in three discrete groups (Fig. 3). The first cluster consists of the populations of the WMCD, DMCD and SMCD. On a purely geographic basis these three populations represent

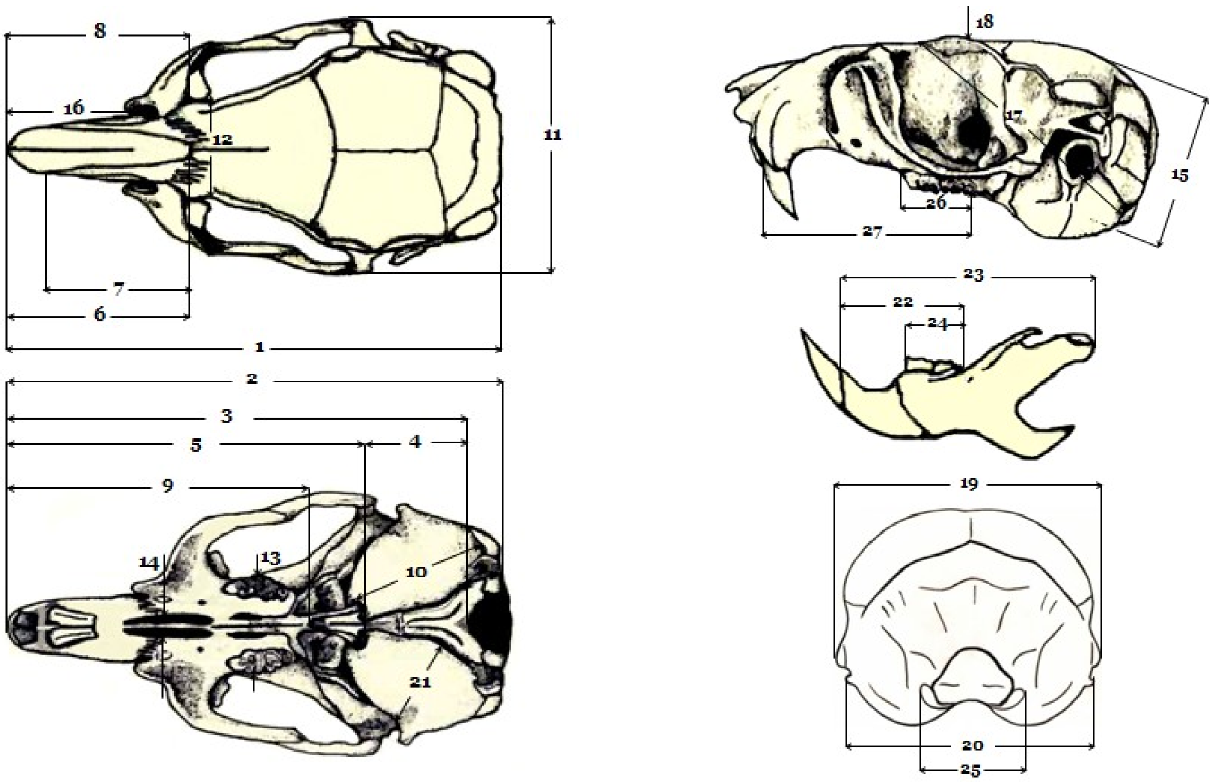

Fig. 2. Skull measurements of dorsal and ventral views of *Gerbillus andersoni* used in this study: (1) GLS- Greatest length of the skull, (2) CBL- Condylobasal length, (3) BL- Basal length, (4) BCL- Basicranial length, (5) BFL- Basifacial length, (6) VCL- Vescirocranial length, (7) NL- Greatest length of the nasals, (8) SL -Snout length, (9) PL -Palatal length, (10) ABL- Greatest length of the auditory bulla, (11) ZB -Zygomatic breadth, (12) MnIW-Minimum interorbital width, (13) MxPW- Maximum palatal width, (14) MnPW- Minimum palatal width, (15) DB- Depth of braincase,(16) IF- Prosthion, (17) FM- Foramen magnum frontal length, (18) PDT- Palatal depth behind tooth row, (19) MxWB- Maximum width of braincase, (20) WAM-Width across auditory meatus,(21) WB- Width of bulla, (22) MT- Mandiblular tooth row, (23) M- Mandible length, (24) MPL- Molar premolar length, (25) WOC- Width of occipital condyles, (26) MPU- Molar premolar length and(27) IM-Incisor molar length

Table 2. External, cranial and dental measurements for specimens from the six studied ecogeographical areas of Egypt. All measurements are in mm unless otherwise indicated

Character	WMCD *G. a. inflatus*	DMCD *G. a. andersoni*	SMCD *G. a. bonhotei*	FD *G. amoenus*	W. el Natroun *G. amoenus*	Siwa *G. campestris*
External measurements						
BM (g)	25.62**±4.54 (13.32-33.5)21	20.87**±7.99 (8-34.79)16	25.07**±3.74 (20.8-30.5)6	13.93**±3.89 (8.0-22.5)6	17.22**±2.81 (14.12-20.9)4	40.08**±0.41 (32.21-48.38)6
TBL	86.48**±7.38 (74.3-100.0)22	85.23**±11.89 (64.3-104.0)16	90.75**±4.29 (85.4-97.0)6	72.34**±6.48 (63.6-84.4)6	82.50**±4.80 (77.0-87.0)4	109.67**±3.93 (102-113)6
TL	117.06**±8.2 (104.7-134.5)21	114.47**±14.80 (95.5-136.0)16	119.12**±2.77 (115.6-123.0)6	94.04**±9.88 (77.8-110.0)5	103.33**±1.5 (102-105)3	137.60**±6.54 (130-146)5
EL	13.62**±1.51 (10.9-15.7)21	13.91**±1.09 (11.9-15.0)16	10.98**±0.98 (9.9-12.3)6	11.06**±0.80 (10.0-13.0)6	10.75**±0.96 (10.0 -12.0)4	16.00** ±1.79 (13.0-18.0)6
HFL	27.08**±1.26 (25.1-29.6)21	29.42**±3.13 25.0-36.0)16	25.15**±1.96 (23.5-28.80)6	21.28**±0.98 (19.8-23.00)6	22.25±0.50 22.0-23.0)4	27.83±0.41 (27.0-28.0) 6
FFL	9.10**±1.67 (5.0-11.7)21	9.97**±1.17 (8.9- 12.50)16	9.93**±0.59 (9-10.60)6	7.60**±0.90 (6.00-9.10)6	7.00**± 0.00 (7.00 -7.00)4	10.00**±0.0 (10.0-10.0)6
TL/TBL	1.36*±0.07 (1.19-1.41)21	1.35*±0.15 (1.05-1.69)16	1.31*±0.03 (1.27-1.35)6	1.31*±0.12 (1.19-1.58)5	1.28*±0.05 (1.22-1.32)3	1.26*±0.05 (1.17-1.30)5
Cranial measurements						
GLS	28.82**±0.95 (25.5-30.1)21	27.61**±2.53 (23.40-32.6)15	27.45**±0.64 (26.5-28.40)6	24.28**±1.74 (21.5-27.00)6	24.80**±0.75 (23.7-25.40)4	32.30**±1.04 (30.7-33.2)6
CBL	27.90**±1.09 (24.4-29.5)21	26.72 **±2.83 (22.0-31.9)14	26.48**±0.71 (25.3-27.30)6	23.28**±1.69 (20.8-25.50)6	24.35**±0.76 (23.30-25.1)4	31.70**±1.15 (30.0-32.7)6
BL	25.84**±1.1 (22.4-27.4)21	24.72**±2.67 (20.00-29.9)14	24.62**±0.86 (23-25.40)6	21.54**±1.92 (18.5-24.30)6	22.63**±0.98 (21.5-23.20)3	29.70**±1.09 (28.3-30.7)6
BCL	6.24**±1.28 (5.0-9.10)21	5.44**±0.94 (3.8-6.6)15	5.10**±0.37 (4.5-5.50)6	4.84**±0.66 (4.00-6.20)6	5.63**±0.25 (5.40 - 5.90)3	6.67**±0.39 (6.30 - 7.20)6
BFL	19.60**±1.87 (14.8-21.3)21	19.18**±1.91 (16.0-23.3)14	19.52**±0.52 (18.5-19.90)6	16.70**±1.38 (14.4-18.7)6	17.20**±0.76 (16.1-17.80)4	23.03**±0.77 (22-23.70)6
VCL	11.0**±0.43 (10.2-1.8)21	10.56**±1.70 (7.70-14.0)15	10.35**±0.50 (9.8-11.10)6	9.02**±0.92 (7.0-11.10)6	9.53**±0.21 (9.30 -9.70)4	12.62**±0.48 (12.1-13.5)6
NL	10.15**±0.39 (9.4-11)21	9.44**±1.29 (7.4-12.0) 14	9.15**±0.62 (8-9.80)6	8.23**0.82 (6.30-10.0)6	8.75**±0.26 (8.4-9.0)4	11.53**±0.47 (10.9-12.20)6
SL	12.35**±0.96 (9.4-13.4)21	11.06**±1.60 (8.8-15.0)15	12.35**±0.40 (11.9-13.0)6	9.21**±1.15 (7.1-11.3)6	9.68**±0.46 (9.20-10.30)4	13.38**±0.74 (12.6-14.4)6
PL	16.62**±1.14 (12.6-17.5)21	16.26**±2.05 (12.5 -20.0)15	16.62**0.50 (15.8-17.20)6	14.30**±1.13 (12.4-15.7)6	15.23**±0.49 (14.6-15.70)4	20.07**±0.68 (19.2-20.70)6
ABL	10.24**±0.36 (9.70-11.0)21	8.66**±0.94 (7.80-11.5)16	9.77**±0.16 (9.6-10.00)6	8.35**±0.61 (7.10-9.20)6	7.55**±0.17 (7.30-7.70)4	8.03**±0.31 (7.60 - 8.40)6
ZB	15.61**±0.48 (14.20-16.2)21	15.28**±1.19 (13.4 -17.4)14	14.77**±0.44 (14-15.20)6	13.10**±0.69 (12.1-14.2)6	13.85**±0.34 (13.5-14.30)4	16.92**±0.68 (16.1-18.0)6
MnIW	5.61**±0.23 (5.3- 6.2)21	5.39**±0.49 (4.90-6.80)16	5.70**±0.49 (5-6.30)6	4.32**±0.28 (3.80-4.70)6	5.13**±0.05 (5.10-5.20)4	6.07**±0.16 (5.80-6.20)6
MXPW	5.59**±0.15 (5.20-5.90)21	5.65**±0.24 (5.30-6.30)16	4.92**±0.37 (4.2-5.20)6	4.72**±0.21 (4.40-5.0)6	5.03**±0.05 (5.00-5.10)4	(5.78**±0.20) (5.50-6.10)6
MnPW	2.96**±0.10 (2.7-3.10)21	2.97**±0.24 (2.60-3.5)16	2.83**±0.21 (2.5-3.0)6	2.33**±0.17 (2.0-2.60)6	2.83**±0.21 (2.60-3.10)4	3.70**±0.18 (3.50-4.0)6
DB	9.12**±0.42 (8.6-10.0)21	9.06**±0.65 (7.9-10.0)15	9.20**±0.51 (8.4-9.90)6	7.67**±0.37 (6.90-8.20)6	7.27**± 0.15 (7.10 -7.40)3	8.72**±0.40 (8.10 - 9.20)6
IF	9.84**±0.48 (8.2-10.4)21	9.42**±1.33 (7.2-11.8)15	9.48**±0.65 (9-10.50)6	8.02**±0.87 (6.60-9.10)6	8.70**±0.48 (8.0-9.0)4	11.70**±0.39 (11.0 - 12.0)6
FM	14.43**±0.53 (13.1-15.5)21	13.81**±1.01 (12.0-16.0)16	13.87**±0.37 (13.3-14.10)6	12.43**±0.53 (11.5-13.3)6	13.23**±0.38 (12.7-13.5)4	15.75**±0.90 (14.0-16.5)6
PDT	9.00**±0.24 (8.50-9.6)21	8.66**±0.73 (7.40-9.8)16	8.53**±0.45 (8.2-9.40)6	7.53**±0.36 (7.00-8.20)6	8.38**±0.22 (8.10 -8.60)4	9.28**±0.24 (9.0-9.7)6
MXWB	14.80**±0.31 (14-15.3)21	13.91**±1.00 (12.6-16.3)15	13.85**±0.42 (13-14.1)6	12.56**±0.64 (11.3-13.5)6	13.38**±0.30 (13.0-13.7)4	15.50**±0.33 (15.1-16.1)6
WAM	13.12**±0.25 (12.6-13.6)21	12.45**±0.62 (11.5-14.0)16	12.45**±0.38 (11.8-12.90)6	11.06**±0.31 (10.5-11.5)6	11.55**±0.25 (11.2-11.8)4	13.47**±0.29 (13.0-13.9)6

WB	6.00**±0.59 (5.5-7.6)21	5.26**±0.36 (4.60 - 6.10)16	5.33**±0.25 (5-5.70)6	4.92**±0.20 (4.60-5.20)16	5.48**±0.36 (5.0 - 5.80)4	5.58**±0.24 (5.3-6.0)6
MT	7.93**±0.30 (7.2-8.5)21	7.99**±0.45 (7.2-8.8)16	7.72**±0.90 (7-9.4)6	6.71**±0.43 (6.3-7.6)15	7.45±0.41 (7.10-7.90)4	9.03**±0.66 (8.0-9.70)6
M	15.29**±0.80 (13.1-16.1)21	14.36**±1.03 (13.0-15.8)16	14.57**±1.63 (13.1-17.50)6	12.49**±0.68 (11.5-13.9)15	12.68**±0.75 (11.8-13.3)4	16.25**±0.79 (15.1-17.5)6
MPL	4.40 **±0.22 (4.0-4.80)21	4.47**±0.11 (4.30-4.70)16	4.12**±0.47 (3.7-5.0)6	3.71**±0.20 (3.40-4.10)15	4.28**±0.22 (4.00-4.50)4	5.23**±0.24 (5.00-5.60)6
WOC	6.18**±0.31 (5.70-6.80)21	5.67**±0.27 (5.20-6.10)15	5.47**±0.16 (5.3-5.70)6	4.63**±0.15 (4.30-4.90)16	5.00**±0.17 (4.80-5.10)3	6.55**±0.22 (6.30-6.90)6
MPU	4.12**±0.17 (3.8-4.4)21	4.24**±0.25 (3.80-4.60)15	3.77**±0.23 (3.5-4.0)6	3.46**±0.19 (3.20-3.80)16	4.28**±0.13 (4.10-4.40)4	5.25**±0.36 (4.60-5.60)6
AP	5.23**± 0.36 (4.2-5.9)21	4.76**±0.58 (3.9-6.1)16	4.85**±0.18 (4.6-5.0)6	4.08**±0.26 (3.6-4.5)16	4.30**±0.18 (4.10-4.50)4	6.03**±0.16 (5.90-6.30)6
PP	2.11**± 0.13 (2.0-2.5)21	2.13**±0.12 (2.0-2.4)16	2.03**±0.15 (1.8-2.2)6	2.03**±0.17 (1.8-2.5)16	2.10**±0.18 (1.9-2.3)4	2.52**±0.25 (2.3-3.0)6
IM	13.36**±0.45 (12.0-13.9)21	13.02**±1.33 (10.8-15.4)16	12.62**±0.41 (12-13.0)6	11.34**±0.67 (10.2-12.4)16	12.15**±0.21 (11.9-12.4)4	15.73**±0.67 (14.7-16.3)6

Data shown as mean±SD (range) number of specimens (*=significant, **=highly significant)

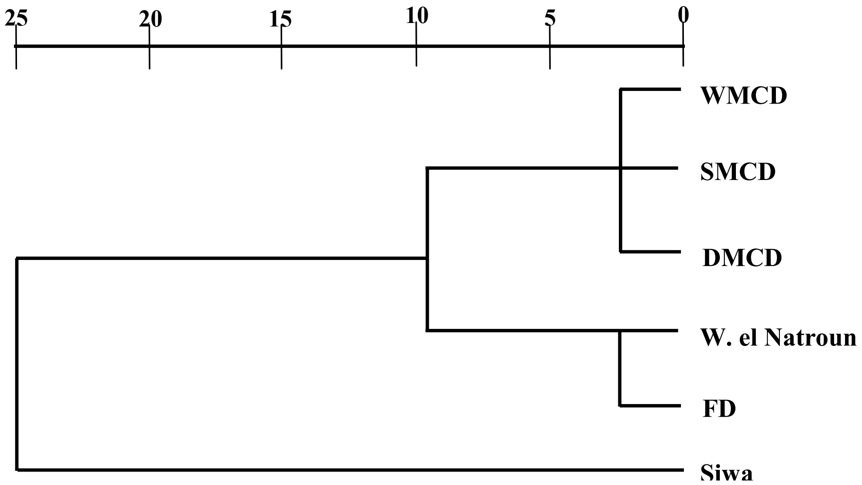

Fig. (3): A dendrogram showing the similarity between the selected *Gerbillus* sppassemblages of the Siwa oasis, western Mediterranean coastal desert (WMCD), wadi el Natroun, El Faiyum depression (FD), Delta Mediterranean coastal desert (DMCD) and Sinai Mediterranean coastal desert (SMCD) based on external, cranial and dental measurements

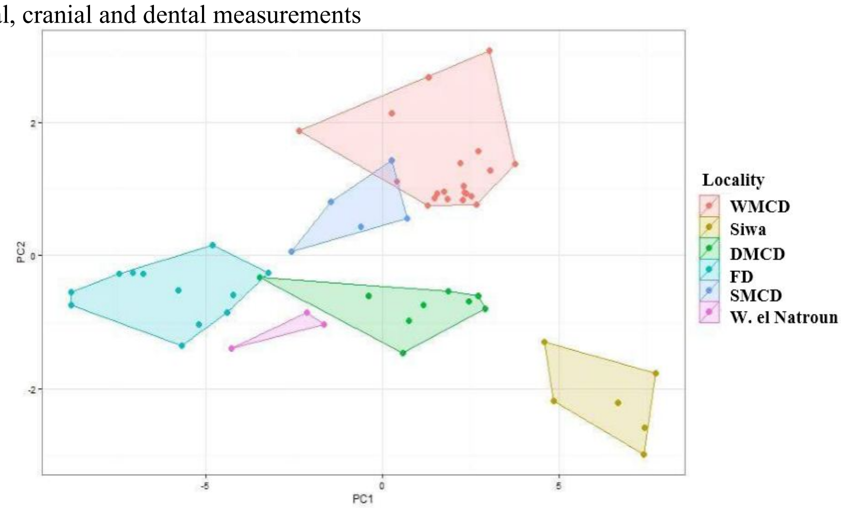

Fig. (3). Principle component analysis of the cranial and dental measurements of the populations of six clusters by localities the three Gerbillus andersoni subspecies; G. a. inflatus, G. a. andersoni and G. a. bonhotei respectively. Further examination of animals of this cluster shows all the typical G. andersoni characters, including the hairy feet, which characterizes the subgenus Gerbillus.

The second cluster contains the Wadi el Natroun and FD populations which, on a purely geographical basis, are referable to the species G. amoenus. These animals are morphologically separated from the first group by naked plantar surfaces of hind feet which characterizes the subgenus Hendecapleura. Siwa population, which belongs to the species D. campestris, appears in a cluster of its own and is characterized by its naked plantar surfaces of hind feet which agrees with the subgenus Dipodillus.

Principal Component Analysis (PCA)

Principal component analysis based on 21 variables showing significant, intergroup variables was carried out. The analysis generated two principle components for all samples. The first and second principle component axes (PC1 and PC2 respectively) explained 77.8% and 7.6% of the total variation in samples as shown in Table 3. Factor loading values for each measurement is shown in Table 4.

Figure 4 shows a clear similarity between the two populations of WMCD, SMCD and to a lesser extent between these two population and that of DMCD. Specimens from FD and Wadi el Natroun are somewhat similar but are distinctly separated from both the coastal populations and that of Siwa Oasis, which appears as a distinct group different from all other populations.

Table 3. Results of principal analysis based on 21 variables

Principal component	Eigen value	% explained	% cumulative
1	4.09	77.8	77.8
2	1.29	7.6	85.4

Table 4. Factor loading values for each morphological character

Character	PC1	PC2
GLS	0.240460	-0.027423
CBL	0.240337	-0.050326
BFL	0.220992	-0.140456
VCL	0.232507	-0.031784
NL	0.229291	0.033503
SL	0.224387	0.108068
PL	0.225359	-0.195448
ABL	0.081077	0.684361
ZB	0.239034	0.0237543
MnIW	0.221939	0.105998
MXPW	0.211415	0.046653
MnPW	0.220101	-0.146372
IF	0.229955	-0.107945
FM	0.230326	-0.008666
PDT	0.222804	0.138777
WAM	0.229134	0.204887
WB	0.147474	0.466186
MT	0.225480	-0.140594
M	0.230791	0.054043
MPL	0.213577	-0.164909
MPU	0.205315	-0.28468

According to the cluster and PCA statistical analysis suggest that the subgenus Dipodillus has a higher phenetic distance from the other subgenera and genus Gerbillus considered paraphyletic.

DISCUSSION

Skull features were one of the main arguments used to assess the systematics and the taxonomy of the genus Gerbillus, most previous studies regarded only a limited data set of measures mainly related to the dental and bullae morphology (Lay and Nadler, 1975; Pavlinov, 2001).

The observed morphological similarity between the two-desert subspecies G. a. inflatus of the WMCD and G. a. bonhotei of the SMCD may be a reflection of the arid nature of their habitats. However, when one compares these animals to those of the mesic habitats of the DMCD, it becomes obvious that characters that set these two-desert subspecies apart from G. a. andersoni of the Nile Delta are not the typical desert adaptive characters (Osborn and Helmy, 1980). Most obvious among these are the larger size of these desert animals relative to the smaller size of their mesic habitat counterpart. Desert animals often have larger ears and more inflated auditory bulla than their mesic habitats counterpart, which is not the case in these animals. Population of SMCD is the most closer to the population of the WMCD than other localities. Population of DMCD is the nearest for the WMCD and SMCD than other populations. On the other hand, FD population is the nearest for the population of Wadi el Natroun. Siwa Oasis population is considered the most distant for all populations as shown in Fig. 3.

These results are in agreement with the findings of Younes (2012) who investigated the morphological similarities between G. andersoni populations from different ecogeographical regions in Egypt irrespective of their subspecific affiliations. He demonstrated that G. a. inflatus from the Western Mediterranean coastal desert is more similar to G. a. bonhotei of Sinai coastal desert than G. a. andersoni of Delta Mediterranean coastal desert.

Morphological examination of all currently recognized species clearly demonstrated that species belonging to the subgenus Dipodillus show recognizable modifications in the shape of the rostrum, in the zygomatic plate and especially in the tympanic bullae and the accessory bullae. In fact, the tympanic bullae in G. campestris shows a mediocre development compared to other species and the posterior extremity of the accessory bullae is reduced. Moreover, a narrow zygomatic breadth which accentuates the angle between the anterior edge of posterior part of zygomatic arch and the dorsal root of squamosal is observed in G. campestris. Some of these modifications were suggested to have an adaptive value related to auditory and feeding behavior (Colangelo et al., 2010).

Abiadh et al. (2010a) and Ndiaye et al. (2012; 2016) demonstrated that the subgenera Dipodillus and Gerbillus are sister taxa. However, according to our results, G. campestris which belongs to the subgenus Dipodillus, appears as the most differentiated (Figs. 2 and 3). Moreover, we found a close phenotypic similarity between G. andersoni (subgenus Gerbillus) and G. amoenus (subgenus Hendecapleura). These results are in agreement with the morphological systematic that was introduced for separating Dipodillus from the rest of the genus Gerbillus (Musser and Carleton, 2005; Abiadh et al., 2010b) and disagree with the results reported by Abiadh et al., (2010a).

In conclusion, the current morphological and morphometric analyses allowed us to discriminate three morphological clusters, the first was the subgenus Gerbillus represented by G. andersoni, the second was the subgenus Hendecapleura represented by G. amoenus and the third was the subgenus Dipodillus represented by G. campestris. The separation of Dipodillus from the rest of the genus Gerbillus make it a paraphyletic genus. These results are congruent with the morphological classification adopted by some authors but contrast with a monophyletic genus which was suggested by recent molecular analyses.

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تحليل القياسات الظاهرية لجربلس أندرسوني وجربلس كامبستريز وجربلس أميناس من مصر

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بالرغم من وجود عدد كبير من الدراسات في تصنيف الثدييات الصغيرة، إلا أن القليل جداً منها قد أُجري على الأنواع في مصر. تم دراسة تحليل القياسات المورفولوجية الخارجية وللجمجمة والأسنان لجربلس أندرسوني وجربلس كامبسترز وجربلس أميناس من ثلاث مناطق بيئية جغرافية مختلفة. فمن الناحية المورفولوجية، سمحت لنا التحليلات الإحصائية لمتغيرات قياسات الجمجمة والأسنان بتمييز ثلاث مجموعات مورفولوجية تتناغم هذه المجموعات مع المجموعات الثلاث التي اقترحتها الدراسات المورفولوجية السابقة. ويُلاحظ التشابه الكبير بين عشائر جربلس أندرسونيٍ من صحراء سيناء الساحلية والصحراء الساحلية الغربية للبحر الأبيض المتوسط على الرغم من أنهما مفصولان جغرافياً عن بعضهما البعض بدلتا النيل (حوالي 200ٍ كيلومتراً). وطبقاً للنتائج التي تم الحصول عليها عن طريق استخدام التعنقد وتحليل المكون الرئيسي، وجدنا أنه يوجد اختلافاً كبيراً بين جُنيس ديبوديلاس والجُنيسان الآخران جربلس وهنديكابليورا. وتشير هذه الحقيقة إلى أن الاختلافات المظهرية بين أنواع جنس جربلس لا ترتبط في المقام الأول إلى تاريخه العرقي.