

## RESEARCH ARTICLE

# Regional variation in the cheetah (*Acinonyx jubatus*) revisited: Morphology of wild and captive populations

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## Abstract

The cheetah (*Acinonyx jubatus*) is listed as a vulnerable species by the International Union for the Conservation of Nature (IUCN), including two critically endangered subspecies, the Saharan cheetah, and the Iranian cheetah, so it is imperative that we understand variation in cheetah morphology to make good decisions regarding the conservation of this species. Here, we aim to determine whether northeastern African cheetahs have smaller body sizes than southern African cheetahs. This study also adds to our knowledge of cheetah morphology from two cheetah populations that do not yet have comprehensive published data: Kenya, and northeastern Africa, including captive individuals. We calculated means and standard deviations on cranial and body measurements of live or in few cases, freshly dead, cheetahs from the aforementioned populations, plus previously published data on Namibian and Botswanan cheetahs and compared them to one another using multivariate analysis of variance. Results show that northeastern African cheetahs have smaller body sizes than southern and eastern African populations. We also found that captive cheetahs retain the morphological characteristics of their ancestral population- captive cheetahs from southern Africa have similar body sizes to wild southern African cheetahs and larger body sizes than captives from northeastern Africa. Other analyses regarding cheetah growth agree with previous studies on Namibian and Botswanan cheetah populations rates. As such, this study can serve as a baseline for the care of captive cheetah populations to maintain healthy weights and body proportions.

## KEYWORDS

*A. j. soemmeringii*, body measurements, Botswana, Kenya, Namibia

## 1 | INTRODUCTION

The cheetah (*Acinonyx jubatus*) is a specialized predator, unique among cats because of its adaptation to cursorial locomotion with a lithe and gracile body form. It is classified as vulnerable by IUCN (Durant, Mitchell, Ipavec, & Groom, 2015), but with approximately 7,100 adult or adolescent cheetahs remaining in the wild and the speed of decline reported, it was requested to be up-listed in the red list classification as endangered by the IUCN (Durant et al., 2017). Two subspecies (*A. j. hecki*, *A. j. venaticus*) are already classified as critically endangered (Belbachir, 2008; Jowkar et al., 2008). To make

the best conservation decisions about cheetahs, it is important to understand the differences between cheetahs from different localities and quantify the distinctions both morphologically and genetically. While genetic structure could be identified between cheetah populations (Charruau et al., 2011), the eastern and southern African cheetah were recently merged into a single subspecies (Kitchener et al., 2017), and an overall reduced level of genetic diversity has been documented through multiple genetic tests (reviewed in Schmidt-Küntzel et al., 2018). Previous studies have examined the morphological differences in cheetahs between Namibia, South Africa (Labuschagne, 1979), East Africa (McLaughlin,

**TABLE 1** Means and standard deviations for each measurement for all groups analyzed

Character	All individuals mean $\pm$ SD				
	Botswana	Kenya	Namibia	UAE (North)	UAE (South)
Weight (kg)	42.2 $\pm$ 8.2 <sup>UN</sup>	41.7 $\pm$ 5.3 <sup>UN</sup>	40.4 $\pm$ 7.0 <sup>UN</sup>	29.3 $\pm$ 3.2 <sup>N, B, K</sup>	41.0 $\pm$ 12.4
Upper canines, R (cm)	2.24 $\pm$ 0.21 <sup>N, K</sup>	1.67 $\pm$ 0.20 <sup>B, N, U</sup>	2.09 $\pm$ 0.28 <sup>B, K</sup>	2.11 $\pm$ 0.24 <sup>K</sup>	-
Lower canines, R (cm)	1.60 $\pm$ 0.21 <sup>K</sup>	1.13 $\pm$ 0.30 <sup>UN, B, N</sup>	1.53 $\pm$ 0.21 <sup>K</sup>	1.56 $\pm$ 0.12 <sup>K</sup>	-
Skull length (cm)*	16.0 $\pm$ 3.0	18.2 $\pm$ 3.7	15.4 $\pm$ 1.3	14.3 $\pm$ 0.6	-
Skull width (cm)	13.7 $\pm$ 1.7	14.8 $\pm$ 5.5	13.8 $\pm$ 1.1	12.6 $\pm$ 0.6	-
Muzzle length (cm)	7.6 $\pm$ 1.4	7.6 $\pm$ 1.9	7.0 $\pm$ 1.7	5.7 $\pm$ 0.5	-
Muzzle girth (cm)	26.2 $\pm$ 1.9	26.2 $\pm$ 1.8	26.9 $\pm$ 2.8	23.5 $\pm$ 0.7	-
Chest girth (cm)	73.4 $\pm$ 5.6 <sup>N, UN</sup>	66.3 $\pm$ 7.5 <sup>UN</sup>	68.3 $\pm$ 5.1 <sup>UN, B</sup>	60.1 $\pm$ 3.4 <sup>N, B, K, US</sup>	71.4 $\pm$ 6.6 <sup>UN</sup>
Abdomen girth (cm)	57.5 $\pm$ 5.6 <sup>UN, K</sup>	60.2 $\pm$ 8.6 <sup>UN, B, N</sup>	57.2 $\pm$ 8.1 <sup>UN, K</sup>	48.2 $\pm$ 3.9 <sup>N, B, K, US</sup>	59.8 $\pm$ 6.9 <sup>UN</sup>
Body length (cm)	126.6 $\pm$ 12.6 <sup>UN</sup>	116.6 $\pm$ 12.2	122.9 $\pm$ 8.4 <sup>UN</sup>	112.4 $\pm$ 5.9 <sup>B, N</sup>	120.8 $\pm$ 11.9
Tail length (cm)	77.5 $\pm$ 5.9 <sup>N, UN</sup>	68.8 $\pm$ 14.5	74.5 $\pm$ 5.5 <sup>B, UN</sup>	68.2 $\pm$ 4.9 <sup>B, N</sup>	71.3 $\pm$ 5.5
Overall body length (cm)	204.1 $\pm$ 15.5 <sup>UN</sup>	185.5 $\pm$ 19.9	197.7 $\pm$ 11.7 <sup>UN</sup>	180.7 $\pm$ 9.3 <sup>N, B</sup>	191.6 $\pm$ 15.5
Foreleg total, R (cm)	74.9 $\pm$ 4.3 <sup>UN</sup>	68.1 $\pm$ 5.0	74.0 $\pm$ 4.8 <sup>UN</sup>	68.3 $\pm$ 4.7 <sup>B, N</sup>	67.8 $\pm$ 3.8
Shoulder to elbow, R (cm)	39.2 $\pm$ 2.4 <sup>UN</sup>	36.4 $\pm$ 3.1	38.4 $\pm$ 3.6 <sup>UN</sup>	35.0 $\pm$ 2.9 <sup>B, N</sup>	36.8 $\pm$ 4.81
Elbow to heel, R (cm)	41.1 $\pm$ 2.8 <sup>K, UN, US, N</sup>	35.9 $\pm$ 2.7 <sup>B</sup>	39.1 $\pm$ 3.0 <sup>B, UN</sup>	35.9 $\pm$ 2.7 <sup>B, N</sup>	36.4 $\pm$ 5.6 <sup>B</sup>
Hindleg total, R (cm)	76.8 $\pm$ 5.9 <sup>UN</sup>	73.6 $\pm$ 5.2	78.4 $\pm$ 5.3 <sup>UN</sup>	71.4 $\pm$ 3.7 <sup>B, N</sup>	72.0 $\pm$ 7.1
Hip to knee, R (cm)	36.1 $\pm$ 4.5 <sup>UN</sup>	36.9 $\pm$ 7.4	35.6 $\pm$ 4.6	31.9 $\pm$ 2.9 <sup>B</sup>	32.7 $\pm$ 5.6
Knee to heel, R (cm)	45.6 $\pm$ 3.1	42.3 $\pm$ 2.7	45.9 $\pm$ 6.1	41.3 $\pm$ 7.0	41.1 $\pm$ 4.9
Front foot length, R (cm)	7.9 $\pm$ 0.5	7.5 $\pm$ 0.6	7.9 $\pm$ 0.6	7.2 $\pm$ 0.3	-
Front foot width, R (cm)	5.9 $\pm$ 0.4 <sup>UN</sup>	5.4 $\pm$ 0.4 <sup>B, N</sup>	5.9 $\pm$ 0.5 <sup>UN</sup>	4.9 $\pm$ 0.2 <sup>B, N</sup>	-
Hind foot length, R (cm)	9.0 $\pm$ 0.5 <sup>UN</sup>	8.6 $\pm$ 0.6	8.8 $\pm$ 0.7	7.7 $\pm$ 0.2 <sup>B</sup>	-
Hind foot width, R (cm)	6.0 $\pm$ 0.4	5.5 $\pm$ 0.4	6.1 $\pm$ 0.6	5.3 $\pm$ 0.1	-
Testicle length, R (cm)	3.2 $\pm$ 0.3 <sup>N</sup>	-	2.7 $\pm$ 0.5 <sup>B</sup>	2.9 $\pm$ 0.5	3.4 $\pm$ 0.4 <sup>N</sup>
Testicle width, R (cm)	2.4 $\pm$ 0.3 <sup>N</sup>	-	1.9 $\pm$ 0.3 <sup>B, UN, US</sup>	2.3 $\pm$ 0.3 <sup>N</sup>	2.4 $\pm$ 0.3 <sup>N</sup>

Note: Raw data can be downloaded from Dryad. Sample sizes for each individual measurement are included in the Supporting Information. All *p* values can be found in Appendix 1. Starred variables had unequal variances and were analyzed using Tamhane's post hoc test. All other data were analyzed using Tukey's post hoc test. All significance is at the  $\alpha = .05$  level. Only age classes >3 were used in this analysis. B = significantly different from Botswana; K = significantly different from Kenya; N = significantly different from Namibia; UN = significantly different from UAE Northeast African; US = significantly different from UAE South African.

Abbreviations: R, right side; SD, standard deviation; UAE, United Arab Emirates.

1970), and Serengeti National Park (Caro, 1994), but the measurements for the latter three regions only included mass, body and tail length, chest girth, and shoulder height, so as a result, the comparisons were not as comprehensive as possible (Marker & Dickman, 2003). A later study by Boast, Houser, Good, and Gusset (2013) used a comprehensive set of measurements and were able to compare the cheetah populations in Namibia and Botswana. No live northeastern African cheetahs have been included in morphometric studies to date.

In this study, we aim to examine the hypothesized difference in size between northeastern and southern African cheetahs. For this, we include a new dataset of cheetahs from Kenya (formerly *A. j. raineyii*), and from a group of captive cheetahs from the United Arab Emirates (UAE) that originated in northeast Africa and are comparing them to animals from southern Africa using the same set of measurements as Marker and Dickman (2003) and Boast et al. (2013). The dataset of southern Africa includes a larger sample size

of Namibian cheetahs (*A. j. jubatus*)—the largest dataset of cheetahs to date—previously published data on Botswanan cheetahs, as well as captive cheetahs from the UAE that originated in southern Africa (*A. j. jubatus*). Having morphological data on captive cheetah populations to contrast with wild populations can help us determine if captive populations have the same morphology as wild populations, both for the purposes of determining morphological plasticity, and inferring the health status of captive populations as compared to their wild counterparts. By understanding what body types or measurements wild cheetahs have, we can help determine if captive individuals are over or underweight, which is indicative of nutritional or health imbalances. Here, we aim to ascertain if north African cheetah populations have significantly smaller body sizes than cheetah populations from southern Africa. The end-goal of this study is to share this information to provide a baseline for conservation biologists and captive cheetah caregivers to better inform optimal management practices.

**TABLE 2** Means and standard deviations for each measurement for males only in the four groups analyzed

Character	Males, mean ± SD			
	Botswana	Namibia	UAE (North)	UAE (South)
Weight (kg)*	44.8 ± 9.0 <sup>UN</sup>	42.8 ± 6.4 <sup>UN</sup>	29.3 ± 3.2 <sup>B,N</sup>	41.0 ± 12.4
Upper canines, R (cm)	2.32 ± 0.21 <sup>N</sup>	2.14 ± 0.27 <sup>B</sup>	2.11 ± 0.23	–
Lower canines, R (cm)	1.67 ± 0.15	1.59 ± 0.19	1.56 ± 0.12	–
Skull length (cm)*	16.2 ± 3.2	15.7 ± 1.3	14.4 ± 0.6	–
Skull width (cm)	14.3 ± 0.9 <sup>UN</sup>	14.1 ± 1.2 <sup>UN</sup>	12.6 ± 0.7 <sup>B,N</sup>	–
Muzzle length (cm)	7.6 ± 0.9	7.3 ± 1.9	5.7 ± 0.5	–
Muzzle girth (cm)	27.1 ± 1.5	27.4 ± 3.2	23.5 ± 0.7	–
Chest girth (cm)	75.7 ± 5.5 <sup>N,UN</sup>	70.0 ± 4.6 <sup>B,UN</sup>	60.1 ± 3.4 <sup>B,N,US</sup>	71.4 ± 6.6 <sup>UN</sup>
Abdomen girth (cm)	59.1 ± 5.9 <sup>UN</sup>	58.9 ± 8.7 <sup>UN</sup>	48.2 ± 3.8 <sup>B, N,US</sup>	59.8 ± 6.9 <sup>UN</sup>
Body length (cm)*	130.2 ± 14.8 <sup>UN,N</sup>	124.4 ± 8.6 <sup>UN,B</sup>	112.5 ± 5.9 <sup>B,N</sup>	120.8 ± 11.9
Tail length (cm)	79.6 ± 3.6 <sup>N,UN,US</sup>	75.5 ± 5.7 <sup>B,UN</sup>	68.2 ± 4.9 <sup>N,B</sup>	71.3 ± 5.5 <sup>B</sup>
Overall body length (cm)	209.8 ± 17.0 <sup>N,UN</sup>	199.3 ± 17.5 <sup>B,UN</sup>	183.0 ± 0 <sup>B,N</sup>	191.6 ± 15.5
Foreleg total, R (cm)*	76.3 ± 4.1 <sup>UN</sup>	75.0 ± 4.9 <sup>UN</sup>	68.3 ± 4.7 <sup>B,N</sup>	67.8 ± 3.8
Shoulder to elbow, R (cm)	40.1 ± 2.5 <sup>UN</sup>	38.9 ± 3.2 <sup>UN</sup>	35.0 ± 2.9 <sup>B,N</sup>	36.8 ± 4.81
Elbow to heel, R (cm)*	41.7 ± 3.1 <sup>N,UN</sup>	39.3 ± 2.5 <sup>B, UN</sup>	35.9 ± 2.7 <sup>B,N</sup>	36.4 ± 5.6
Hindleg total, R (cm)	78.2 ± 6.1 <sup>UN,US</sup>	79.1 ± 6.1 <sup>UN,US</sup>	71.4 ± 3.7 <sup>B,N</sup>	72.0 ± 7.1 <sup>B,N</sup>
Hip to knee, R (cm)	36.5 ± 3.0 <sup>UN</sup>	36.1 ± 4.8 <sup>UN</sup>	31.9 ± 2.9 <sup>B,N</sup>	32.7 ± 5.6
Knee to heel, R (cm)	46.8 ± 2.6	46.2 ± 6.7	41.3 ± 7.0	41.1 ± 4.9
Front foot length, R (cm)	8.0 ± 0.6	8.0 ± 0.6	7.2 ± 0.3	–
Front foot width, R (cm)	6.1 ± 0.5 <sup>UN</sup>	6.1 ± 0.5 <sup>UN</sup>	4.9 ± 0.2 <sup>B,N</sup>	–
Hind foot length, R (cm)	9.1 ± 0.5 <sup>UN</sup>	8.9 ± 0.6 <sup>UN</sup>	7.7 ± 0.2 <sup>B,N</sup>	–
Hind foot width, R (cm)	6.1 ± 0.4	6.3 ± 0.5 <sup>UN</sup>	5.3 ± 0.1 <sup>N</sup>	–
Testicle length, R (cm)	3.2 ± 0.3 <sup>N,K</sup>	2.7 ± 0.5 <sup>B, US</sup>	2.9 ± 0.5	3.4 ± 0.4 <sup>N</sup>
Testicle width, R (cm)	2.4 ± 0.3 <sup>N</sup>	1.9 ± 0.3 <sup>B, UN,US</sup>	2.3 ± 0.3 <sup>N</sup>	2.4 ± 0.3 <sup>N</sup>

Note: Raw data can be downloaded from Dryad. Sample sizes for each individual measurement are included in the Supporting Information. All *p* values can be found in Appendix 2. Starred variables had unequal variances and were analyzed using Tamhane's post hoc test. All other data were analyzed using Tukey's post hoc test. All significance is at the  $\alpha = .05$  level. Only age classes >3 were used in this analysis. B = significantly different from Botswana; K = significantly different from Kenya; N = significantly different from Namibia; UN = significantly different from UAE Northeast African; US = significantly different from UAE South African.

Abbreviations: R, right side; SD, standard deviation; UAE, United Arab Emirates.

## 2 | MATERIALS AND METHODS

In this study, we compiled body mass and external morphological measurements from previously published data on 64 Botswanan cheetahs (Boast et al., 2013) and 241 wild Namibian cheetahs (Marker & Dickman, 2003; both *A. j. jubatus*), and from new unpublished data. Our new dataset includes 203 additional wild Namibian individuals (for a total of 444 Namibian cheetahs), 13 cheetahs from Kenya (formerly *A. j. raineyi*, now *A. j. jubatus*) and a group of 12 northeast African (*A. j. soemmeringii*) and five South African (*A. j. jubatus* from around DeWildt cheetah preserve, South Africa) male cheetahs that now reside in captivity in the UAE at one of the following facilities: Al Ain Zoo, Emirates Park Zoo, Al Bustan Zoological Centre, or Sheikh Butti bin Juma Al Maktoum Wildlife Centre.

All measurements were taken as in the published Namibian dataset (Marker & Dickman, 2003); see this publication for data on how cheetahs were captured before measurement. All data were

recorded and compiled as in Marker and Dickman (2003). Measurements of the cheetahs in Kenya were taken by Action for Cheetahs in Kenya (ACK) trained by author L. M. The UAE cheetah data were taken by author L. M. All measurements were taken in the same way, and all measurements were made on live, anesthetized individuals with the exception of six animals (three from Namibia, two from Botswana, one from Kenya) for which no bloating was present as they had died recently. For five deceased animals from Namibia which were bloated, waist girth was avoided and only bony measurements were taken. None of the UAE cats were dead. All live animals fasted for 12–24 hr before the anesthetic procedure during which the measurements were taken, thus avoiding overblown measurements due to full stomachs. In addition to mass and morphological data, additional data analyzed included ontogenetic age, sex, and locality (or country). All raw and mean data are indexed in Dryad, per Dryad's terms of service (<https://doi.org/10.5061/dryad.95x69p8fg>).

**TABLE 3** Means and standard deviations for each measurement for females only the three groups analyzed

Character	Females, mean $\pm$ SD		
	Botswana	Kenya	Namibia
Weight (kg)	38.5 $\pm$ 5.3	41.7 $\pm$ 5.8 <sup>N</sup>	35.6 $\pm$ 5.3 <sup>K</sup>
Upper canines, R (cm)	2.13 $\pm$ 0.19 <sup>K,N</sup>	1.66 $\pm$ 0.21 <sup>B,N</sup>	1.98 $\pm$ 0.26 <sup>B,K</sup>
Lower canines, R (cm)	1.52 $\pm$ 0.25 <sup>K</sup>	1.07 $\pm$ 0.26 <sup>B,N</sup>	1.42 $\pm$ 0.19 <sup>K</sup>
Skull length (cm)	15.6 $\pm$ 2.8	16.7 $\pm$ 1.0	15.1 $\pm$ 2.6
Skull width (cm)*	13.0 $\pm$ 2.2	13.3 $\pm$ 3.2	13.2 $\pm$ 0.9
Muzzle length (cm)	7.6 $\pm$ 1.9 <sup>N</sup>	6.7 $\pm$ 1.0	6.5 $\pm$ 1.2 <sup>B</sup>
Muzzle girth (cm)	25.1 $\pm$ 1.9	26.5 $\pm$ 1.2	25.9 $\pm$ 1.5
Chest girth (cm)	70.2 $\pm$ 3.9 <sup>N</sup>	69.6 $\pm$ 3.3	65.2 $\pm$ 5.1 <sup>B</sup>
Abdomen girth (cm)	55.3 $\pm$ 4.4 <sup>K</sup>	65.8 $\pm$ 6.6 <sup>B,N</sup>	54.0 $\pm$ 5.6 <sup>K</sup>
Body length (cm)	121.7 $\pm$ 6.4	120.1 $\pm$ 9.2	120.1 $\pm$ 7.2
Tail length (cm)	74.8 $\pm$ 7.1	75.0 $\pm$ 4.0	72.4 $\pm$ 4.5
Overall body length (cm)	196.5 $\pm$ 9.0	193.0 $\pm$ 0	192.1 $\pm$ 12.5
Foreleg total, R (cm)	73.1 $\pm$ 3.9	69.9 $\pm$ 3.4	72.0 $\pm$ 4.0
Shoulder to elbow, R (cm)	38.1 $\pm$ 1.6	37.7 $\pm$ 1.2	37.3 $\pm$ 4.1
Elbow to heel, R (cm)	40.3 $\pm$ 2.2	36.5 $\pm$ 1.9	38.6 $\pm$ 3.7
Hindleg total, R (cm)*	75.0 $\pm$ 5.4	74.6 $\pm$ 1.8	76.8 $\pm$ 2.7
Hip to knee, R (cm)	35.5 $\pm$ 5.9	37.1 $\pm$ 1.7	34.6 $\pm$ 3.9
Knee to heel, R (cm)	44.3 $\pm$ 3.1	41.5 $\pm$ 3.0	44.9 $\pm$ 5.3
Front foot length, R (cm)	7.8 $\pm$ 0.4	7.5 $\pm$ 0.3	7.7 $\pm$ 0.5
Front foot width, R (cm)	5.7 $\pm$ 0.3	5.5 $\pm$ 0.4	5.7 $\pm$ 0.5
Hind foot length, R (cm)	8.8 $\pm$ 0.3	8.2 $\pm$ 0.1	8.6 $\pm$ 0.7
Hind foot width, R (cm)*	5.8 $\pm$ 0.3	5.6 $\pm$ 0.4	5.9 $\pm$ 0.5

Note: Raw data can be downloaded from Dryad. Sample sizes for each individual measurement are included in the Supporting Information. All *p* values can be found in Appendix 3. Starred variables had unequal variances and were analyzed using Tamhane's post hoc test. All other data were analyzed using Tukey's post hoc test. All significance is at the  $\alpha = .05$  level. Only age classes >3 were used in this analysis. B = significantly different from Botswana; K = significantly different from Kenya; N = significantly different from Namibia.

Abbreviation: R, right side; SD, standard deviation.

Our data were broken down by country, sex, and age. Ages were broken into eight groups: (a) 0–6 months, (b) >6–12 months, (c) >12–18 months, (d) >18–30 months, (e) >30–48 months, (f) >48–96 months, (g) >96–144 months, and (h) >144 months (Marker & Dickman, 2003). To analyze differences between countries, we ran multivariable analyses of variance (MANOVA), using Tukey's (equal variances) or Tamhane's (unequal variances) *post hoc* tests, where appropriate—a homogeneity of variance test was run on all data to determine variability between groups in our dataset. Given the statistical differences between countries, datasets were kept separate for further analysis. For sexual dimorphism analyses, each country was run as a separate analysis using an independent samples *t* test to look for differences between males and females. We excluded juveniles in age Classes 1 and 2 as those groups were not found to be sexually dimorphic. We did not run sexual dimorphism analyses on Kenyan or UAE samples as sample sizes were too low and/or only one sex was present. However, we did look for differences between male or female-only samples in age Groups 3–8 for all countries. Additionally, we used polynomial regression to examine the relationship between age and maximum weight, using all

individuals, (i.e., the age where individuals reach the maximum weight or maximum body size) for each country separately. All statistical analyses were run using SPSS v.22 (IBM, 2013) and statistical significance was defined as  $p < .05$  in all cases. Sample sizes for each analysis and measurement can be found in the supplementary information (Table S1).

### 3 | RESULTS

MANOVA analyses (excluding age Groups 1 and 2) reveal some differences between countries (Table 1 and Appendix 1). As found previously in Boast et al. (2013) Botswanan cheetahs appear longer and heavier than all other groups but the only group that was significantly different was the North African UAE group, which was significantly smaller than all other groups. The Namibian and Botswanan cheetahs only differed significantly from each other in the size of their upper canines, chest girth, tail length, and testicle size, for which the Botswanan cheetahs had significantly higher measurements (see Table 1).

Results from male cheetahs can be found in Table 2 and Appendix 2. Botswanan male cheetahs and the captive population from the UAE of southern African ancestry have the largest testicles of all the populations measured, which were significantly larger than Namibian males, followed closely by the UAE captive cheetahs of northeastern African ancestry. Namibian males had the smallest testicle size measured. Even though statistical significance was found between groups with low sample sizes, it should be noted that Type 2 error may be present.

Our data analysis for only females revealed the opposite size and mass pattern as in males (Table 3 and Appendix 3). Although we had no females in the captive UAE sample for comparison, the Kenyan females were the largest, significantly so in weight, and abdomen girth.

Canine measurements were particularly smaller in Kenyan females than the other two groups. The sample size was small for the Kenyan females ( $n = 8$ ); so, this result may change with a larger sample size.

Sexual size dimorphism is marked and significant in Namibian cheetahs and Botswanan cheetahs. See Table 4. All measurements were sexually dimorphic in the Namibian cheetah sample and most measurements were dimorphic in the Botswana sample except

muzzle length, elbow to heel length, total hindlimb length, hip to knee length, forefoot length, and hind foot length. The Kenyan sample was too small for a statistical comparison.

Our data from the polynomial regressions of weight and age group agree with previous data from Marker and Dickman (2003)—that cheetahs reach maximum body size between 49 and 96 months (Figure 1). For this analysis, only Namibia and Botswana had sample sizes were large enough to be considered. We also ran a regression with all cheetahs in the sample.

## 4 | DISCUSSION

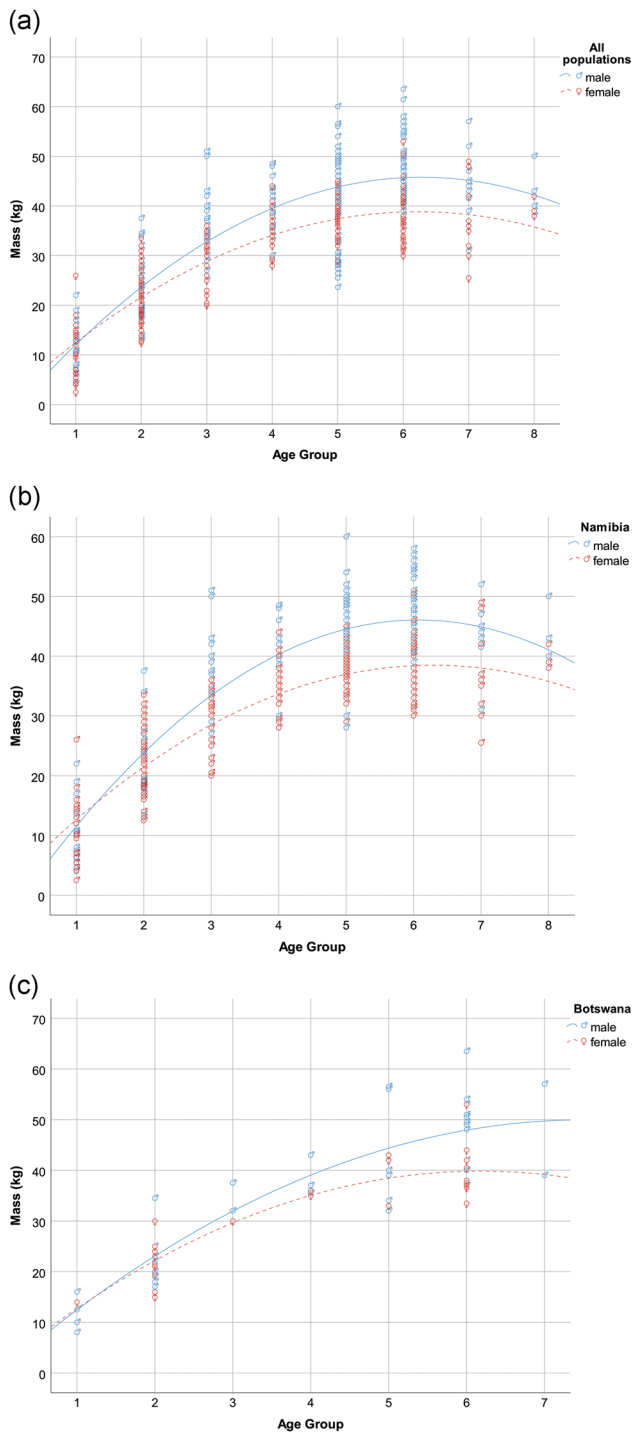
Our study adds two new important data points to the work previously done on cheetahs—the Kenyan sample and the northeast African cheetah sample. As a general trend, Kenyan data were rarely significantly different due to a small sample size and a large variance. However, we were able to tease out a few trends from the Kenya data.

Interestingly, abdominal girth appears to be significantly larger in cheetahs from Kenya than all other groups except the UAE southern

**TABLE 4** Means  $\pm$  SD of sexually dimorphic measurements from *t* test analyzed for each country separately

Character	Sexual dimorphism, mean $\pm$ SD					
	Namibian ♂ ( $n = 298$ )	Namibian ♀ ( $n = 146$ )	Botswana ♂ ( $n = 24$ )	Botswana ♀ ( $n = 17$ )	Kenya ♂ ( $n = 3$ )	Kenya ♀ ( $n = 8$ )
Mass (kg)	42.7 $\pm$ 6.5*	35.6 $\pm$ 5.4*	44.8 $\pm$ 9.0*	38.5 $\pm$ 5.2*	31.5 $\pm$ 2.1	43.6 $\pm$ 1.5
Upper canines, R	2.1 $\pm$ 0.3*	1.98 $\pm$ 0.3*	2.3 $\pm$ 0.2*	2.1 $\pm$ 0.2*	–	–
Lower canines, R	1.59 $\pm$ 0.2*	1.41 $\pm$ 0.2*	1.7 $\pm$ 0.1*	1.5 $\pm$ 0.2*	–	–
Skull length	15.7 $\pm$ 1.3*	15.1 $\pm$ 2.5*	16.3 $\pm$ 3.3	15.6 $\pm$ 2.8	–	–
Skull width	14.1 $\pm$ 1.1*	13.2 $\pm$ 0.9*	14.3 $\pm$ 0.9*	13.0 $\pm$ 2.2*	–	–
Muzzle length	7.2 $\pm$ 1.7*	6.6 $\pm$ 1.2*	7.6 $\pm$ 0.9	7.5 $\pm$ 1.9	–	–
Muzzle girth	27.3 $\pm$ 3.5*	25.9 $\pm$ 1.5*	27.1 $\pm$ 1.5*	25.1 $\pm$ 1.9*	–	–
Chest girth	69.9 $\pm$ 4.5*	65.2 $\pm$ 5.1*	75.7 $\pm$ 5.6*	70.2 $\pm$ 3.9*	–	–
Abdomen girth	58.9 $\pm$ 8.6*	54.1 $\pm$ 5.6*	59.1 $\pm$ 5.9*	55.4 $\pm$ 4.4*	–	–
Body length	124.6 $\pm$ 7.4*	120.2 $\pm$ 7.3*	130.2 $\pm$ 14.8*	121.7 $\pm$ 6.4*	–	–
Tail length	75.7 $\pm$ 4.9*	72.4 $\pm$ 4.6*	79.6 $\pm$ 3.6*	74.7 $\pm$ 7.2*	–	–
Overall body length	199.8 $\pm$ 15.9*	191.2 $\pm$ 16.7*	209.8 $\pm$ 17.0*	196.5 $\pm$ 9.0*	–	–
Total foreleg, R	75.2 $\pm$ 4.0*	71.8 $\pm$ 3.9*	76.3 $\pm$ 4.1*	73.1 $\pm$ 3.9*	–	–
Shoulder to elbow, R	39.0 $\pm$ 2.8*	37.3 $\pm$ 4.1*	40.0 $\pm$ 2.5*	38.1 $\pm$ 1.6*	–	–
Elbow to heel, R	39.3 $\pm$ 2.1*	38.5 $\pm$ 3.7*	41.7 $\pm$ 3.1	40.3 $\pm$ 2.2	–	–
Total hindlimb, R	79.3 $\pm$ 5.1*	76.8 $\pm$ 2.7*	78.2 $\pm$ 6.1	75.0 $\pm$ 5.4	–	–
Hip to knee, R	36.1 $\pm$ 4.5*	34.6 $\pm$ 3.8*	36.5 $\pm$ 3.0	35.5 $\pm$ 5.9	–	–
Knee to heel, R	46.4 $\pm$ 6.4*	44.9 $\pm$ 5.3*	46.8 $\pm$ 2.6*	44.3 $\pm$ 3.1*	–	–
Forefoot length, R	8.0 $\pm$ 0.6*	7.7 $\pm$ 0.5*	8.0 $\pm$ 0.6	7.8 $\pm$ 0.4	–	–
Forefoot width, R	6.1 $\pm$ 0.5*	5.7 $\pm$ 0.5*	6.1 $\pm$ 0.5*	5.7 $\pm$ 0.3*	–	–
Hind foot length, R	8.9 $\pm$ 0.6*	8.6 $\pm$ 0.7*	9.1 $\pm$ 0.5	8.8 $\pm$ 0.3	–	–
Hind foot width, R	6.3 $\pm$ 0.6*	5.9 $\pm$ 0.5*	6.1 $\pm$ 0.4*	5.8 $\pm$ 0.3*	–	–

Note: Statistical significance between sexes is indicated with an \*. Only age classes  $>3$  were used in this analysis. Abbreviation: R, right side; SD, standard deviation.



**FIGURE 1** Growth curves for each sex in different cheetah populations; (a) all cheetahs analyzed here, males:  $y = -1.93 + 15.2 \times -1.21 \times 2$ ,  $R^2 = 0.759$ , females:  $y = 1.43 + 12.02 \times -0.97 \times 2$ ,  $R^2 = 0.770$ ; (b) Namibian cheetahs, males:  $y = -3.4 + 16.3 \times -1.34 \times 2$ ,  $R^2 = 0.808$ , females:  $y = 1.94 + 11.63 \times -0.92 \times 2$ ,  $R^2 = 0.763$ ; (c) Botswanan cheetahs, males:  $y = 0.04 + 13.29 \times -0.88 \times 2$ ,  $R^2 = 0.809$ , females:  $y = 1.23 + 12.5 \times -1.01 \times 2$ ,  $R^2 = 0.823$  [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

African captives, while for all other body parts the Kenyan cheetahs appear to have smaller measurements than all other southern African cheetahs measured here.

Our Kenyan cheetah sample has significantly smaller canines than other cheetahs. While smaller canine size could be a consequence of increased tooth wear, the records have no mention of tooth erosion or fracture and are thus considered to be real. Smaller canines in both male and female cheetahs from Kenya would suggest decreased ability to dispatch prey quickly (Biknevicius & Van Valkenburgh, 1996), but, cheetahs already have reduced canine size relative to other big cats and this subsequent size decrease may not have a functional consequence (Van Valkenburgh & Ruff, 1987). Smaller canines may also imply decreased sexual dimorphism (Gittleman & Van Valkenburgh, 1997), which may be the case in the Kenyan cheetah population. More data on male Kenyan cheetahs are needed to assess this.

The Kenyan population was comparable to the southern African population in terms of morphometrics, which is consistent with the recent merging of the two subspecies (Kitchener et al., 2017). When we compare our data to those reported by Caro (1994) of *A. j. raineyii* (now synonymized with *A. j. jubatus*) from Serengeti National Park in Tanzania, Caro's data are most similar to our small Kenyan sample. This is not surprising since the Serengeti also has a small part of the park in Kenya, and the Tanzanian and Kenyan cheetah population are expected to be largely connected. For body mass, the Caro (1994) data fall closest to our results from Kenya, but others are not appreciably different. For overall body length and chest girth, Caro's (1994) data again fall closest to our Kenyan data, smaller than Botswana and Namibia. Since our Kenyan data align well with Caro's (1994) data, we can conclude that although our sample size is very small, they are relatively good indicators of Kenyan cheetah morphology.

Cheetahs from the UAE are a captive sample from two different regions: northeastern Africa and southern Africa. Despite being composed of only males, the captive population in the UAE of northeastern African ancestry had the lightest body weight of all the groups, had the smallest abdominal girth overall, and consistently was smaller than the Botswanan and Namibian populations. The captive UAE cheetahs from southern Africa showed body proportions close to those of the Botswanan and Namibian wild populations. These two captive samples are important because when compared with wild cheetah populations they offer preliminary evidence that suggests that northeastern African cheetahs are smaller than southern African populations in almost every aspect of their morphology, except the testes, and also that captive animals retain the morphology of their ancestral population. Since the two cheetah populations were both raised in captivity in the UAE, diets, housing quarters, and exercise should be comparable. However, the captives from southern Africa were significantly larger than the captives from northeastern Africa, suggesting a genetic signature as the likely cause. Smaller northeastern African cheetahs have been a topic of speculation, but with no literature support to back up this claim until now.

Our results of the other cheetah populations show that Botswanan cheetahs have the largest overall body size of all groups; however, only the northeastern African group was significantly smaller than Botswana. Additionally, we found that Botswanan cheetahs had significantly larger chest girth than Namibian cheetahs, and sexual dimorphism was present in both Botswanan and Namibian populations, especially pronounced in Namibian cheetahs.

Like Marker and Dickman (2003), we found that cheetahs reach their maximum growth between 49 and 96 months of age, including the expanded samples from Kenya, UAE, and Botswana. Our results on Botswanan and Namibian cheetah populations are also in agreement with Boast et al. (2013).

This study can serve as a baseline for care of captive cheetah populations to maintain healthy weights and body proportions. If caretakers know which region a cheetah (or its ancestors) came from, this study will give them information on normal body proportions, which can provide an estimate of health in captive populations. For example, healthy weights for captive cheetahs from northeastern Africa should be lower than those for cheetahs from southern Africa.

This study adds morphological data from cheetah populations in Kenya and Northeastern Africa, which are important data to better understand wild cheetah population health. In the future, we hope to be able to collect data from more male cheetahs from Kenya, and also from wild individuals (including females) from northeastern African populations.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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**APPENDIX 1: MANOVA  $p$  VALUES FOR ALL ADULT INDIVIDUALS,  $p$  VALUES OF .000 INDICATE  $p < .001$**

Character	Country	Namibia	Kenya	Botswana	UAE Northeast	UAE South
Weight (kg)	Namibia	-	1.000	.852	.000	1.000
	Kenya	1.000	-	1.000	.018	1.000
	Botswana	.852	1.000	-	.000	1.000
	UAE North	.000	.018	.000	-	.518
	UAE South	1.000	1.000	1.000	.518	-
Upper canines	Namibia	-	.005	.003	.995	-
	Kenya	.005	-	.000	.035	-
	Botswana	.003	.000	-	.611	-
	UAE North	.995	.035	.611	-	-
	UAE South	-	-	-	-	-
Lower canines	Namibia	-	.000	.123	.978	-
	Kenya	.000	-	.000	.005	-
	Botswana	.123	.000	-	.943	-
	UAE North	.978	.005	.943	-	-
	UAE South	-	-	-	-	-
Skull length	Namibia	-	.912	.864	.227	-
	Kenya	.912	-	.982	.620	-
	Botswana	.864	.982	-	.066	-
	UAE North	.227	.620	.066	-	-
	UAE South	-	-	-	-	-
Skull width	Namibia	-	.297	.998	.200	-
	Kenya	.297	-	.362	.999	-
	Botswana	.998	.362	-	.256	-
	UAE North	.200	.999	.256	-	-
	UAE South	-	-	-	-	-
Muzzle length	Namibia	-	.978	.182	.406	-
	Kenya	.978	-	.737	.846	-
	Botswana	.182	.737	-	.147	-
	UAE North	.406	.846	.147	-	-
	UAE South	-	-	-	-	-
Muzzle girth	Namibia	-	.993	.560	.358	-
	Kenya	.993	-	.997	.598	-
	Botswana	.560	.997	-	.556	-
	UAE North	.358	.598	.556	-	-
	UAE South	-	-	-	-	-
Chest girth	Namibia	-	.884	.000	.000	.689
	Kenya	.884	-	.677	.001	.997
	Botswana	.000	.677	-	.000	.933
	UAE North	.000	.001	.000	-	.001
	UAE South	.689	.997	.933	.001	-
Abdomen girth	Namibia	-	.005	1.000	.001	.949
	Kenya	.005	-	.014	.000	.431
	Botswana	1.000	.014	-	.003	.971

(Continues)



	UAE North	.001	.000	.003	-	.044
	UAE South	.949	.431	.971	.044	-
Body length	Namibia	-	.969	.080	.001	.983
	Kenya	.969	-	.627	.558	1.000
	Botswana	.080	.627	-	.000	.635
	UAE North	.001	.558	.000	-	.386
	UAE South	.983	1.000	.635	.386	-
Tail length	Namibia	-	.987	.006	.001	.643
	Kenya	.987	-	.412	.354	.971
	Botswana	.006	.412	-	.000	.079
	UAE North	.001	.354	.000	-	.799
	UAE South	.643	.971	.079	.799	-
Overall body length	Namibia	-	.994	.053	.015	.958
	Kenya	.994	-	.728	.727	1.000
	Botswana	.053	.728	-	.000	.458
	UAE North	.015	.727	.000	-	.705
	UAE South	.958	1.000	.458	.705	-
Foreleg total, R	Namibia	-	.212	.969	.018	.849
	Kenya	.212	-	.104	.999	1.000
	Botswana	.969	.104	-	.007	.772
	UAE North	.018	.999	.007	-	1.000
	UAE South	.849	1.000	.772	1.000	-
Shoulder to elbow, R	Namibia	-	.987	.589	.014	.852
	Kenya	.987	-	.844	.562	.994
	Botswana	.589	.844	-	.004	.584
	UAE North	.014	.562	.004	-	.875
	UAE South	.852	.994	.584	.875	-
Elbow to heel, R	Namibia	-	.339	.000	.007	.300
	Kenya	.339	-	.012	.996	1.000
	Botswana	.000	.012	-	.000	.010
	UAE North	.007	.996	.000	-	.998
	UAE South	.300	1.000	.010	.998	-
Hindleg total, R	Namibia	-	.056	.494	.001	.821
	Kenya	.056	-	.594	.321	.999
	Botswana	.494	.594	-	.010	.956
	UAE North	.001	.321	.010	-	1.000
	UAE South	.821	.999	.956	1.000	-
Hip to knee, R	Namibia	-	.941	.940	.065	.729
	Kenya	.941	-	.991	.206	.602
	Botswana	.940	.991	-	.048	.609
	UAE North	.065	.206	.048	-	.998
	UAE South	.729	.602	.609	.998	-
Knee to heel, R	Namibia	-	.494	1.000	.096	.522
	Kenya	.494	-	.582	1.000	1.000
	Botswana	1.000	.582	-	.196	.596
	UAE North	.096	1.000	.196	-	1.000
	UAE South	.522	1.000	.596	1.000	-

(Continues)

Front foot L, R	Namibia	-	.539	.968	.204	-
	Kenya	.539	-	.483	.929	-
	Botswana	.968	.483	-	.179	-
	UAE North	.204	.929	.179	-	-
	UAE South	-	-	-	-	-
Front foot W, R	Namibia	-	.568	.998	.006	-
	Kenya	.568	-	.576	.169	-
	Botswana	.998	.576	-	.007	-
	UAE North	.006	.169	.007	-	-
	UAE South	-	-	-	-	-
Hind foot L, R	Namibia	-	.361	.346	.099	-
	Kenya	.361	-	.146	.707	-
	Botswana	.346	.146	-	.044	-
	UAE North	.099	.707	.044	-	-
	UAE South	-	-	-	-	-
Hind foot W, R	Namibia	-	.115	.339	.124	-
	Kenya	.115	-	.486	.812	-
	Botswana	.339	.486	-	.283	-
	UAE North	.124	.812	.283	-	-
	UAE South	-	-	-	-	-
Testicle L, R	Namibia	-	-	.000	.458	.016
	Kenya	-	-	-	-	-
	Botswana	.000	-	-	.623	.756
	UAE North	.458	-	.623	-	.340
	UAE South	.016	-	.756	.340	-
Testicle W, R	Namibia	-	-	.000	.009	.043
	Kenya	-	-	-	-	-
	Botswana	.000	-	-	.893	1.000
	UAE North	.009	-	.893	-	.976
	UAE South	.043	-	1.000	.976	-

Abbreviation: UAE, United Arab Emirates.

## APPENDIX 2: MANOVA $p$ VALUES FOR ADULT MALES ONLY, $p$ VALUES OF 0.000 INDICATE $p < .001$

Character	Country	Namibia	Botswana	UAE Northeast	UAE South
Weight (kg)	Namibia	-	.860	.000	1.000
	Botswana	.860	-	.000	.986
	UAE North	.000	.000	-	.355
	UAE South	1.000	.986	.355	-
Upper canines	Namibia	-	.006	.944	-
	Botswana	.006	-	.141	-
	UAE North	.944	.141	-	-
	UAE South	-	-	-	-
Lower canines	Namibia	-	.158	.880	-
	Botswana	.158	-	.348	-

(Continues)

	UAE North	.880	.348	-	-
	UAE South	-	-	-	-
Skull length	Namibia	-	.783	.076	-
	Botswana	.783	-	.054	-
	UAE North	.076	.054	-	-
	UAE South	-	-	-	-
Skull width	Namibia	-	.735	.028	-
	Botswana	.735	-	.020	-
	UAE North	.028	.020	-	-
	UAE South	-	-	-	-
Muzzle length	Namibia	-	.655	.214	-
	Botswana	.655	-	.136	-
	UAE North	.214	.136	-	-
	UAE South	-	-	-	-
Muzzle girth	Namibia	-	.936	.239	-
	Botswana	.936	-	.311	-
	UAE North	.239	.311	-	-
	UAE South	-	-	-	-
Chest girth	Namibia	-	.000	.000	.905
	Botswana	.000	-	.000	.230
	UAE North	.000	.000	-	.000
	UAE South	.905	.230	.000	-
Abdomen girth	Namibia	-	.999	.000	.996
	Botswana	.999	-	.002	.999
	UAE North	.000	.002	-	.046
	UAE South	.996	.999	.046	-
Body length	Namibia	-	.016	.000	.708
	Botswana	.016	-	.000	.087
	UAE North	.000	.000	-	.315
	UAE South	.708	.087	.315	-
Tail length	Namibia	-	.004	.000	.250
	Botswana	.004	-	.000	.006
	UAE North	.000	.000	-	.679
	UAE South	.250	.006	.679	-
Overall body length	Namibia	-	.045	.000	.864
	Botswana	.045	-	.000	.195
	UAE North	.000	.000	-	.640
	UAE South	.864	.195	.640	-
Foreleg total, R	Namibia	-	.795	.003	.552
	Botswana	.795	-	.001	.432
	UAE North	.003	.001	-	1.000
	UAE South	.552	.432	1.000	-
Shoulder to elbow, R	Namibia	-	.315	.001	.463
	Botswana	.315	-	.000	.156
	UAE North	.001	.000	-	.723
	UAE South	.463	.156	.723	-

(Continues)

Elbow to heel, R	Namibia	-	-	.012	.902
	Botswana	.009	.009	.000	.487
	UAE North	.012	.000	-	1.000
	UAE South	.902	.487	1.000	-
Hindleg total, R	Namibia	-	.537	.000	.004
	Botswana	.537	-	.000	.046
	UAE North	.000	.000	-	.997
	UAE South	.004	.046	.997	-
Hip to knee, R	Namibia	-	.954	.021	.495
	Botswana	.954	-	.032	.425
	UAE North	.021	.032	-	.990
	UAE South	.495	.425	.990	-
Knee to heel, R	Namibia	-	.982	.059	.386
	Botswana	.982	-	.090	.362
	UAE North	.059	.090	-	1.000
	UAE South	.386	.362	1.000	-
Front foot L, R	Namibia	-	.999	.069	-
	Botswana	.999	-	.087	-
	UAE North	.069	.087	-	-
	UAE South	-	-	-	-
Front foot W, R	Namibia	-	.808	.001	-
	Botswana	.808	-	.001	-
	UAE North	.001	.001	-	-
	UAE South	-	-	-	-
Hind foot L, R	Namibia	-	.474	.018	-
	Botswana	.474	-	.009	-
	UAE North	.018	.009	-	-
	UAE South	-	-	-	-
Hind foot W, R	Namibia	-	.445	.037	-
	Botswana	.445	-	.106	-
	UAE North	.037	.106	-	-
	UAE South	-	-	-	-
Testicle L, R	Namibia	-	.000	.458	.016
	Botswana	.000	-	.623	.756
	UAE North	.458	.623	-	.340
	UAE South	.016	.756	.340	-
Testicle W, R	Namibia	-	.000	.009	.043
	Botswana	.000	-	.893	1.000
	UAE North	.009	.893	-	.976
	UAE South	.043	1.000	.976	-

Abbreviation: UAE, United Arab Emirates.

**APPENDIX 3: MANOVA  $p$  VALUES FOR ADULT FEMALES ONLY,  $p$  VALUES OF .000 INDICATE  $p < .001$**

Character	Country	Namibia	Kenya	Botswana
Weight (kg)	Namibia	-	.019	.090
	Kenya	.019	-	.419
	Botswana	.090	.419	-
Upper canines	Namibia	-	.035	.045
	Kenya	.035	-	.002
	Botswana	.045	.002	-
Lower canines	Namibia	-	.003	.076
	Kenya	.003	-	.000
	Botswana	.076	.000	-
Skull length	Namibia	-	.627	.662
	Kenya	.627	-	.831
	Botswana	.662	.831	-
Skull width	Namibia	-	.938	.972
	Kenya	.938	-	.989
	Botswana	.972	.989	-
Muzzle length	Namibia	-	.984	.010
	Kenya	.984	-	.442
	Botswana	.010	.442	-
Muzzle girth	Namibia	-	.730	.090
	Kenya	.730	-	.193
	Botswana	.090	.193	-
Chest girth	Namibia	-	.126	.000
	Kenya	.126	-	.969
	Botswana	.000	.969	-
Abdomen girth	Namibia	-	.000	.619
	Kenya	.000	-	.000
	Botswana	.619	.000	-
Body length	Namibia	-	.986	.653
	Kenya	.986	-	.977
	Botswana	.653	.977	-
Tail length	Namibia	-	.641	.457
	Kenya	.641	-	1.000
	Botswana	.457	1.000	-
Overall body length	Namibia	-	.987	.383
	Kenya	.987	-	.953
	Botswana	.383	.953	-
Foreleg total, R	Namibia	-	.163	.421
	Kenya	.163	-	.061
	Botswana	.421	.061	-
Shoulder to elbow, R	Namibia	-	.967	.724
	Kenya	.967	-	.986

(Continues)

	Botswana	.724	.986	-
Elbow to heel, R	Namibia	-	.428	.130
	Kenya	.428	-	.093
	Botswana	.130	.093	-
Hindleg total, R	Namibia	-	.135	.456
	Kenya	.135	-	.989
	Botswana	.456	.989	-
Hip to knee, R	Namibia	-	.376	.618
	Kenya	.376	-	.740
	Botswana	.618	.740	-
Knee to heel, R	Namibia	-	.283	.834
	Kenya	.283	-	.523
	Botswana	.834	.523	-
Front foot L, R	Namibia	-	.752	.421
	Kenya	.752	-	.435
	Botswana	.421	.435	-
Front foot W, R	Namibia	-	.347	1.000
	Kenya	.347	-	.421
	Botswana	1.000	.421	-
Hind foot L, R	Namibia	-	.465	.212
	Kenya	.465	-	.155
	Botswana	.212	.155	-
Hind foot W, R	Namibia	-	.203	.710
	Kenya	.203	-	.483
	Botswana	.710	.483	-