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Body measurements of free-ranging snow leopards across their range

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Abstract

We provide body measurements of snow leopards collected from 55 individuals sampled in five of the major mountain ranges within the species distribution range; the Altai, Hindu Kush, Himalayas, Pamirs and Tien Shan mountains. Snow leopards appear to be similarly sized across their distribution range with mean body masses of 36 kg and 42 kg for adult females and adult males, respectively. In contrast to other large felids, we found little variation in body size and body mass between the sexes; adult males were on average 5% longer and 15% heavier than adult females.

Introduction

The snow leopard's (*Panthera uncia*) elusive behaviour combined with remote and often inaccessible habitat provide great challenges for scientific studies. As a consequence, much of the research around the species relies upon remotely collected data and few records of accurate morphological measurement have been published. Available information suggests a large variation in body measurements such as body mass ranging between 25 and 75 kg having been reported, perhaps inaccurately (Hemmer 1972). Scientists commonly collect standard body measurements and tissue samples, such as hair and blood, during the course of handling anesthetised animals for telemetry-based research and monitoring. These measurements can be used to describe a species morphology, help distinguish taxonomic distinctions of possible subspecies (e.g. Haig et al. 2006) and ultimately develop a better understanding of the species. To provide a more precise description of snow leopard morphology, assess the extent of sexual dimorphism and investigate for possible variation across the species distribution range, we have collated measurements from snow leopards measured in five of the 12 snow leopard range countries.

Methods

Data were collected from 47 snow leopards in the Pamirs (Afghanistan; n=7), Tien Shan (Kyrgyzstan; n=7), Hindu Kush (Pakistan; n=1), and the Altai (Mongolia; n=32) in 2006-2019 (Fig 1). Four of the snow leopards in Afghanistan were measured during captures, the remaining three were found

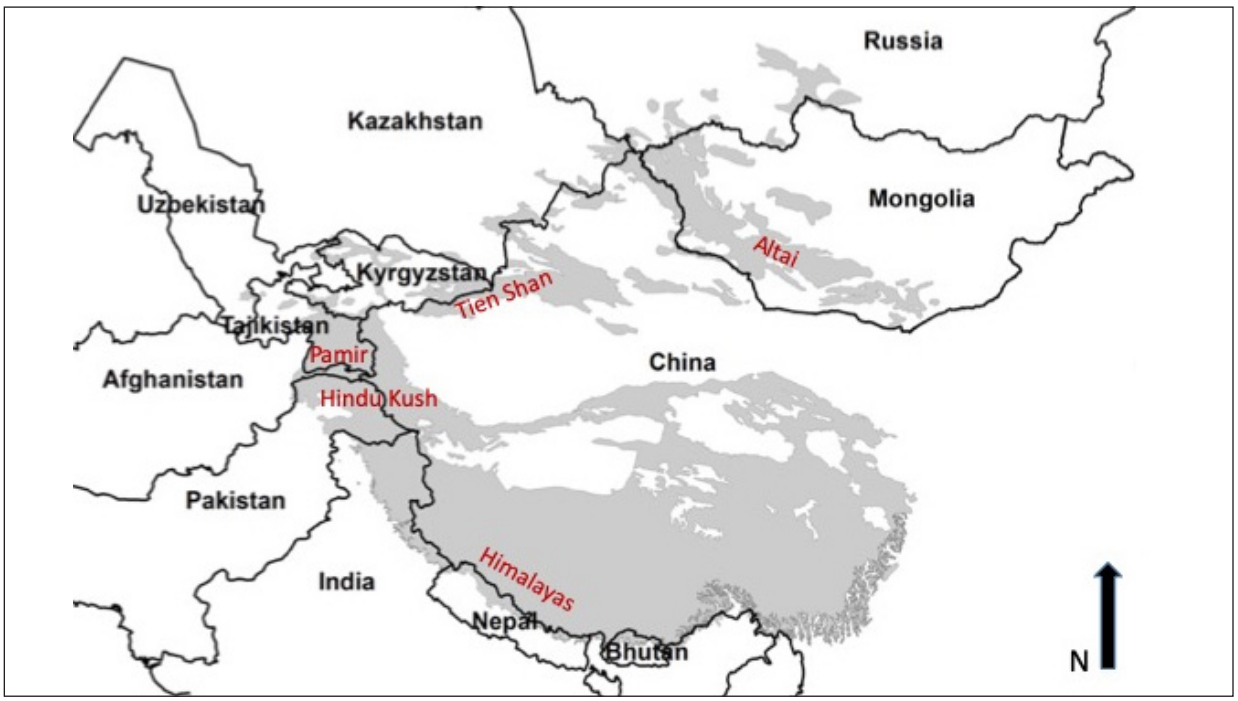

Fig. 1. *Map of the snow leopard distribution range (shaded grey) and the locations of the study areas (mountain ranges in red): Pamir – Hindu Kush; Wakhan Corridor, Afghanistan and Chitral Gol, Pakistan, Tien Shan; Sarychat, Kyrgyzstan, Himalayas; Langu valley, Nepal and Kanchenjunga Nepal, Altai; Tost Mountains, Mongolia.*

dead during field work. All measurements were collected for the cats that were found dead except for body mass when it was estimated that the carcass was older than a few days (n=2). We also included published information from the Himalayas (Nepal; n=8) (Jackson 1996; KCA 2019) in the analyses. Body length of the snow leopards in Kanchenjunga, Nepal did not include the head, we removed these measurements to allow for comparisons. All measurements were collected with measuring tape and spring or digital scales. Age was estimated based on tooth wear and colour, body size, presence of facial scars from territorial disputes and nipple coloration (Johansson et al. 2016). Because large felids grow slowly and do not reach full adult size until 4-5 years of age (Sunquist and Sunquist 2002) and snow leopards are unlikely to reproduce before three years age (Johansson et al. 2021), we classified snow leopards less than or 3 years of age as subadults following Johansson et al. (2016). We provide measurements for body mass (total weight), body length (tip of the nose to base of the tail), tail length (base of the tail to the tip of the last caudal vertebra) and shoulder height (heel of front paw to top of the shoulder blade), see Fig. 2. For individuals that were captured and measured more than once, we provide the average of all measurements except if the animal transitioned between age classes. For individuals that were measured both as subadults and adults (2 females, 6 males), we provide one measurement for each age class respectively. This yielded a total dataset of up to 63 measurements for 55 individuals (19 adult females, 11 subadult females, 23 adult males and 10 subadult males).

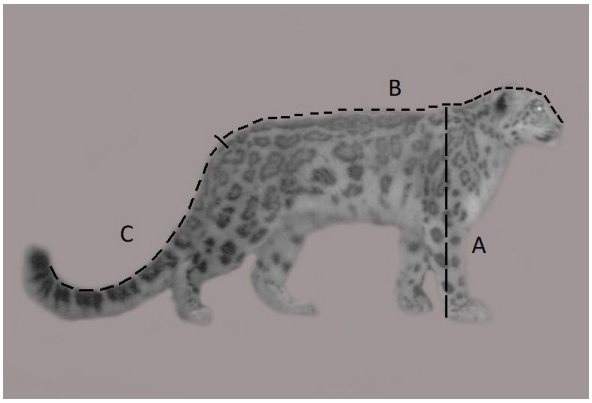

Fig. 2. *Body measurements of snow leopards,*
***A**: shoulder height measured from the heel of the front paw to top of the shoulder blade*
***B**: body length measured from the tip of the nose to base of the tail, and*
***C**: tail length measured from base of the tail to the tip of the last caudal vertebra.*

We tested for variation in snow leopard body length, tail length and body mass among mountain ranges (the Altai mountains, Himalayas, Pamir-Hindu Kush, and Tien Shan), between adult males and females, and along a latitudinal gradient using linear models in R (R Development Core Team, 2019). Because the study areas in Pamirs and Hindu Kush were relatively close to each other we combined these samples into one group (Pamir-Hindu Kush). Comparisons could not be made for shoulder height due to low sample size. Only adult individuals were included in the comparisons because the subadults were still growing and we lacked accurate age estimates, preventing meaningful comparisons. Measurements for subadults are included for reference only.

Results

We did not detect any differences among the mountain ranges in body length (Females: $F(9)=3.5$, $p=0.07$. Males: $F(18)=2.8$, $p=0.09$), tail length (Females: $F(9)=1.3$, $p=0.33$. Males: $F(19)=0.10$, $p=0.96$) or body mass (Females: $F(14)=1.7$, $p=0.21$. Males: $F(17)=0.91$, $p=0.46$) for adult snow leopards (Table 1). Adult males

Table 1. Body measurements of adult snow leopards sampled in four mountain ranges across the snow leopard distribution range. Values are given as mean±SD (n).

SEX	AGE CLASS	MOUNTAIN RANGE	BODY LENGTH	TAIL LENGTH	SHOULDER HEIGHT	BODY MASS
Female	**Adult**					
		Pamirs-Hindu Kush	109±1 (4)	93±1 (4)	67±1 (3)	38±3(3)
		Tien Shan	100±3 (4)	91±1 (4)	-	34±4 (4)
		Altai	108±7 (5)	91±4 (5)	56 (1)	36±2 (10)
		Himalaya	-	-	-	39 (1)
		All mountains	*106±6 (13)*	*92±3 (13)*	*64±5 (4)*	*36±3 (18)*
	Subadult					
		Pamirs-Hindu Kush	111 (1)	94 (1)	68 (1)	-
		Tien Shan	-	-	-	-
		Altai	101±7 (4)	86±5 (4)	-	31± (7)
		Himalaya	-	87±9 (2)	60±4 (2)	27±5 (3)
		All mountains	*103±8 (5)*	*87±6 (7)*	*63±5 (3)*	*30±5 (10)*
Male	**Adult**					
		Pamirs-Hindu Kush	112±2 (4)	95±2 (4)	67±1 (4)	39±5 (3)
		Tien Shan	113±3 (3)	95±7 (3)	-	42±3 (3)
		Altai	118±5 (14)	94±5 (14)	61±3 (4)	43±4 (13)
		Himalaya	-	95±3 (2)	65±7 (2)	41±1 (2)
		All mountains	*116±5 (21)*	*95±4 (23)*	*64±4 (10)*	*42±4 (21)*
	Subadult					
		Pamirs-Hindu Kush	-	-	-	-
		Tien Shan		-	-	- -
		Altai	111±7 (7)	90±3 (7)	59 (1)	36±3 (8)
		Himalaya	-	-	-	34±1 (2)
		All mountains	*111±7 (7)*	*90±3 (7)*	*59 (1)*	*35±3 (10)*

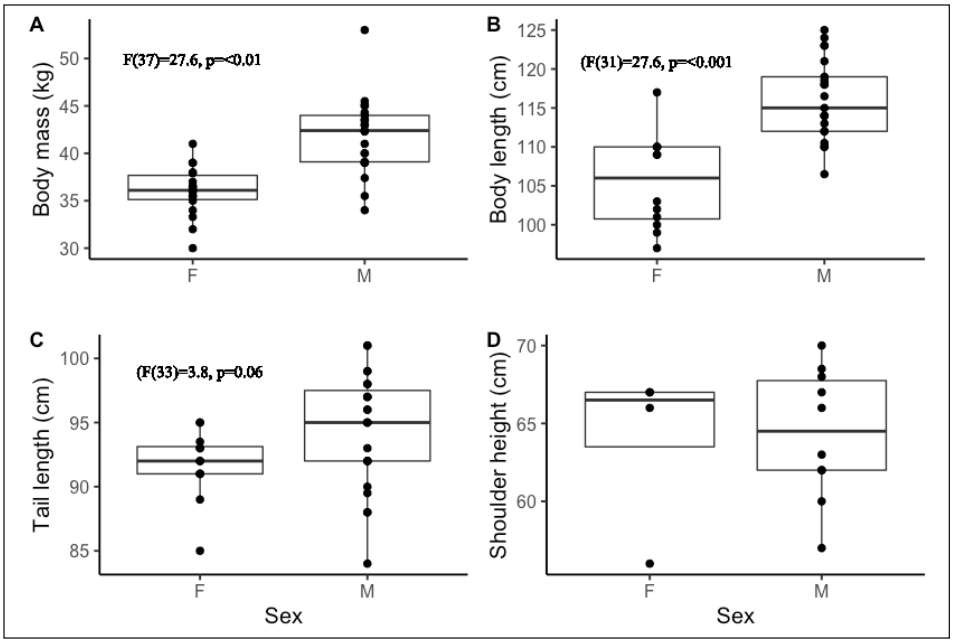

Fig. 3. *Body mass and size of adult snow leopard females and males. The boxes include all values within the 25th and 75th quantile.*

had greater body mass ($F(37)=27.6$, $p=<0.001$) and body length ($F(31)=27.6$, $p=<0.001$) than adult females whereas tail length did not differ ($F(33)=3.8$, $p=0.06$) (Table 1). Adult snow leopard males weighed on average 15% more and had 5% longer bodies than adult females (Table 1). Within the sexes, variation in body mass and size was rather small among adults with 95% of the measurements within ±15% of the mean value (Fig. 3). Mean values (± SD) of the body measurements are presented in Table 1. We did not detect any correlation between body mass and latitude ($F(57)=2.2$, $p=0.14$).

Discussion

Snow leopards appear to be similarly sized across their distribution range. This contrasts to the other solitary-living members of the genus *Panthera* (*P. pardus, P. tigris* and *P. onca*) which vary in size geographically by up to two times (e.g. average weights of adult male leopards range from 31 kg in Cape Mountains, South Africa to 66 kg in Iran; Sunquist and Sunquist 2002, Farhadinia et al. 2014, Hunter 2015). Temperatures in the high-altitude habitat used by the snow leopards are likely more affected by altitude than latitude, which would explain the lack of correlation between latitude and body mass (see Bergmann's rule; Bergmann 1847). Sexual dimorphism is common in mammals with polygynous mating systems where males are commonly larger than females because of increased competition for access to breeding females. However, the difference in body mass and size between adult male and female snow leopards was very small compared to jaguars, leopards and tigers where average male body mass range from 1.4 to 1.7 times the body mass of adult females (Sunquist and Sunquist 2002, Wilson and Mittermeyer 2009, Hunter 2015). Snow leopards also show much less sexual dimorphism in craniomandibular and dental size than the other members of Panthera (Christiansen and Harris 2012). Similarly, individual variation in body mass and size within the sexes was rather small for the adult snow leopards compared to e.g. Persian leopards where adult male weights range from 40 to 91 kg (Farhadinia et al. 2014). Janecka et al. (2017) proposed that three subspecies of snow leopards occur based on three genetic clusters (corresponding to Altai, Himalayas and Tien Shan, Hindu Kush and Pamir), our results indicate that the snow leopards across these clusters are similarly sized. Throughout the snow leopard distribution range, the main available prey range in size from 36 to 72 kg (Lyngdoh et al. 2014), perhaps the snow leopards are optimally sized to hunt these prey in the steep slopes and natural selection prevents individuals from becoming much larger or smaller.

A simple, yet fairly precise description of an averagely-sized snow leopard appears to be a body length of 110 cm, tail length of 90 cm, shoulder height of 65 cm, and body mass of 40 kg and that most males are up to 10% larger whereas females are up to 10% smaller. The greater variation in shoulder height compared to body and tail length is likely due to higher intra and interobserver error depending on how much the front leg was extended when conducting the measurement. These morphological values can be used to calculate standard drug doses for immobilization of free-ranging snow leopards and to improve the husbandry and wellbeing of snow leopards in captivity.

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