

MORPHOMETRIC STUDY ON THE GOBI RED BULL BACTRIAN CAMEL

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ABSTRACT

The experimental data comes from randomly selected 40 bull camels in the 2020 Gobi Red Bull Camel Competition organised in North Urad Banner. In this study, 21 kinds of the actual body size parameters were measured in each camel with an average age of 9.28 year and the main statistical body size of bull camels include: body height 176.30 cm, body length 151.40cm, chest circumference 240.03 cm and ankle circumference 23.68 cm, respectively. At the same time, the front view and side view images of bull camel were collected by digital camera, and then the photo data of body size were obtained with Photoshop. The corresponding photo data of body height is 61.52 cm, body length is 52.13 cm, and line chest circumference is 20.48 cm, respectively. Based on on-site measurement scale $\lambda=2.87$, the actual body data of bull camel were obtained from the corresponding photo data with relatively small error. The three-dimensional chest circumference of bull camel was 4λ times as the line chest circumference on bull camel photo. Many related golden ratio φ were found in Bactrian camel body size data ratio. An optimised formula for estimating the weight of bull camel based on photo data LI_{PD} were derived: $Y(\text{kg})=-773.57+(2.66+4.06\beta_{ABD})\lambda LI_{PD} (\text{cm})$.

Key words: Bactrian camel, golden ratio, morphometry, non-contact measurement, photo data

The Gobi Red Bactrian camel is mainly distributed in the Gobi grassland of north western China and southern Mongolia. The camel wool is purple red, so it is called "Gobi Red Camel" (Batu Suhe, 2019). Like other Bactrian camels the Gobi Red Camel is capable of survival in harsh living environments, being able to consume diets that are often toxic to other mammals and can tolerate extreme water and food deprivation (Surong *et al*, 2018; Dongjirzhab, 2019). It not only provides meat, milk, wool and other living materials, but also is used for riding and transportation. The anatomy of Bactrian camels is scarcely studied (Surong and Dugarsiren, 2013). Present study was, therefore undertaken to study the morphometriy of the Gobi red bull Bactrian camel.

Materials and Methods

At present study, 40 bull camels were randomly selected from Gobi Red Bull Camel Competition organised in North Urad Banner in the winter of 2020, and their body height, body length, chest circumference, ankle circumference and other actual body sizes were measured. Meanwhile, the corresponding size data was extracted from the photos of each bull camel. Through comparing the actual body data and photo data of bull camel, the

error between the actual body data and estimated data from photo data was determined. Finally, various ratio analyses were carried out on the body size data of bull camels.

Measurements and analysis

The definition of height, length and width in the body size of Bull camel

In present study, 21 body size parameter of Gobi red bull camel were defined based on camel anatomy (Surong *et al*, 2013; Su xuebin, 1983), as shown by solid line in Fig 1. The abbreviations of diverse body size parameters are given below but are not repeated in all the tables.

Height of the body (HB): the vertical distance from the bottom of the hump to the ground.

Height of the shoulder (HS): the vertical distance from the highest point of the scapula to the ground.

Height of the pars sacralis (HP): the vertical distance from the highest point of the pars sacralis to the ground.

Height of the fore leg (HFL): the vertical distance from the root of the front thigh to the ground.

Height of the back leg (HBL): the vertical distance from the root of the back thigh to the ground.

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Height of the fore knee (HFK): the vertical distance from the front knee to the ground.

Height of the back knee (HBK): the vertical distance from the back knee to the ground.

Height of the first hump (HFH): the vertical distance from the top of the first hump to the bottom.

Height of the second hump (HSH): the vertical distance from the top of the second hump to the bottom.

Length of the body (LI): the incline distance from the shoulder to the hip.

Length between two humps (LBH): the horizontal distance from the back edge of the front hump to the front edge of the second hump.

Length of the first hump (LFH): the horizontal distance from the front edge of the first hump to the back edge.

Length of the second hump (LSH): the horizontal distance from the front edge of the second hump to the back edge.

In addition, based on camel anatomy (Surong *et al*, 2013; Su xuebin, 1983), the definition of the width and circumference of the bull camel is as follows (not marked on the Fig 1).

Chest circumference (CC): three-dimensional chest circumference formed from the back edge of the front peak down through the centre of the chest.

Line Chest circumference (LCC): the vertical distance formed from the back edge of the front peak down to the base of foreleg in the bull camel photo.

Ankle circumference (AC): The horizontal circumference of the upper third of the forelimb.

Widths of the shoulder (WS): the horizontal distance between the left and right shoulder.

Shoulder width: the horizontal distance between the left and right scapula.

Widths of the pars sacralis (WP): the horizontal distance between the outer sides of the pars sacralis.

Widths of the fore palm (WFP): the distance from the left edge to the right edge of the fore palm.

Length of the fore palm (LFP): the distance from the toe to the heel of the fore palm.

Widths of the hind palm (WHP): the distance from the left edge to the right edge of the hind palm.

Length of the hind palm (LHP): the distance from the toes to the heel of the hind palm.

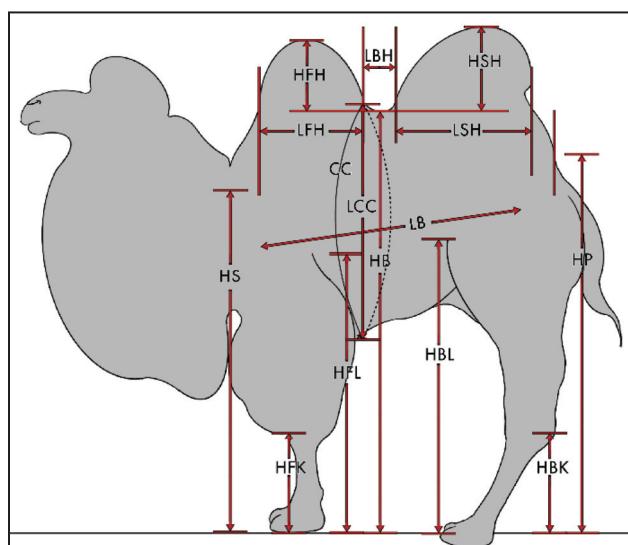


Fig 1. Definition of Bactrian camel body size parameters.

Table 1. The statistical average (AVG) and the standard deviation (SD) of the actual body data of Gobi red bull camel.

| item | age | HB | HS | HP | HFL | HBL | HFK | HBK | HFH | HSH | LI |
|------|-------|--------|--------|--------|--------|--------|-------|-------|-------|-------|--------|
| AVG | 9.28 | 176.30 | 127.48 | 135.13 | 106.33 | 106.48 | 46.88 | 51.73 | 35.53 | 33.03 | 151.40 |
| SD | 2.66 | 5.70 | 6.30 | 6.92 | 6.65 | 8.69 | 4.05 | 5.37 | 4.49 | 5.88 | 11.08 |
| item | LBH | LFFH | LSH | CC | AC | WS | WP | WFP | LFP | WHP | LHP |
| AVG | 23.68 | 43.35 | 53.18 | 240.03 | 23.68 | 60.73 | 55.63 | 21.80 | 21.80 | 18.40 | 19.58 |
| SD | 5.48 | 4.62 | 8.94 | 10.51 | 3.16 | 5.55 | 5.95 | 1.93 | 1.55 | 3.24 | 1.36 |

Table 2. The result of statistical analysis of photo data and ratios.

| item | HB | HS | HP | HFL | HBL | HFK | HBK |
|------|-------|-------|-------|-------|-------|-------|-------|
| AVG | 61.52 | 45.86 | 48.09 | 36.84 | 37.44 | 17.34 | 18.45 |
| SD | 1.59 | 1.62 | 1.99 | 1.71 | 1.21 | 0.72 | 0.62 |
| item | HFH | HSH | LFH | LSH | LBH | LI | LCC |
| AVG | 12.33 | 11.44 | 16.78 | 17.34 | 8.15 | 52.13 | 20.48 |
| SD | 1.45 | 0.98 | 0.49 | 0.50 | 1.11 | 1.78 | 4.45 |

The actual body data (ABD) of the bull camel was obtained by manually using a metre ruler.

Estimation of the actual body data of the bull camel from the photo data

Assuming the scale of the actual body size measurement of the bull camel is λ , then the actual body data (X_{ABD}) of a certain parameter can be estimated based on the corresponding photo data (X_{PD})

$$X_{ABD} = \lambda X_{PD} \quad (1)$$

In present study $\lambda=2.87$.

Ratio analysis of the actual body data and the photo data

Ratio is an important mathematical concept, expressed by the quotient of two variables with the same unit. As shown in Fig 2, assuming that the total length of a line is AB, select a point C and divide the line AB into two parts AC and CB, if the ratio of AB to AC and the ratio of AC to CB is exactly 1.618, then call the point C is the golden section point of the line AB, and ratio 1.618 is called the golden ratio, marked as φ (Gary 2018; Pearce, 2020; Thapa and Thapa, 2018).

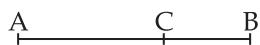


Fig 2. Golden-section

$$\frac{AB}{AC} = \frac{AC}{CB} = 1.618 \quad (2)$$

Optimisation of Bactrian camel weight formula

When evaluating the growth indicators of the Bactrian camel, the weight measurement of the Bactrian camel is a difficult task, so the weight of the camel is generally estimated by some regression empirical formulas, such as equation (3) (Tian *et al*, 1987).

$$Y(\text{kg}) = -773.57 + 2.66X_{ABD}(\text{cm}) + 4.06Z_{ABD}(\text{cm}) \quad (3)$$

where Y , X_{ABD} and Z_{ABD} are the weight, the actual body length and the actual chest circumference of the bull camel, respectively. Perform equivalent transformation on formula (3), that is, first divide the right side by X_{ABD} , and then multiply by X_{ABD} , and get the following formula

$$Y(\text{kg}) = -773.57 + (2.66 + 4.06Z_{ABD}/X_{ABD}) X_{ABD} \text{ (cm)} \quad (4)$$

Let's define actual chest circumference-to-actual body length ratio β_{ABD} as the quotient of the actual chest circumference $Z_{ABD}(\text{CC})$ of a Bactrian camel divided by its actual body length $X_{ABD}(\text{LI})$, that is

$$\beta_{ABD} = CC_{ABD}/LI_{ABD} \quad (5)$$

$$Y(\text{kg}) = -773.57 + (2.66 + 4.06\beta_{ABD}) \lambda LI_{PD} \text{ (cm)} \quad (6)$$

In present study, $\beta_{ABD}=1.571$ and $\lambda=2.87$, so as long as the body length LI_{PD} is extracted from the photo of the bull camel, its weight can be estimated.

Results

The statistical average (AVG) and the standard deviation (SD) of the actual body data of Gobi red bull camel are shown in Table 1 and it was found that the dispersion of the actual body data of bull camels is relatively small.

Extracting the size of the object in the photo and calculating its actual size provide an effective technical basis for non-contact measurement (Adikari *et al*, 2017; Feng Tian, 2014) of certain animals that are difficult to capture or target placed in dangerous places.

In present study, a Canon E05-30D digital camera was used to collect the front view and side view photos of the 40 bull camels (Fig 3). Total of 20 side view photos with good viewing angles were selected, and the photo data (PD) were measured by Photoshop. The result of statistical analysis of photo



Fig 3. Bactrian camel photo: (a) Front view, (b) Side view.



data and ratios are shown in Table 2. The dispersion of the photo data of bull camel is smaller than that of the actual body data.

Table 3. Estimated body data based on the photo data (cm).

| Parameter | HB | HS | HP | HFL | HBL | HFK | HBK |
|-----------|--------|--------|--------|--------|--------|--------|------------|
| PD | 61.52 | 45.86 | 48.09 | 36.84 | 37.44 | 17.34 | 18.45 |
| ED | 176.56 | 131.62 | 138.02 | 105.73 | 108.45 | 49.77 | 52.95 |
| ABD | 176.30 | 127.48 | 135.13 | 106.33 | 106.48 | 46.88 | 51.73 |
| Error (%) | 0.15 | 3.20 | 2.12 | 0.57 | 0.91 | 5.98 | 2.33 |
| Parameter | HFH | HSH | LFH | LSH | LBH | LI | LCC |
| PD | 12.33 | 11.44 | 16.78 | 17.34 | 8.15 | 52.13 | 20.48 |
| ED | 35.39 | 32.83 | 48.16 | 49.77 | 23.39 | 149.61 | 58.78 |
| ABD | 35.53 | 33.03 | 43.35 | 53.18 | 23.68 | 151.40 | 240.03(CC) |
| Error (%) | 0.14 | 0.20 | 10.51 | 6.62 | 0.29 | 1.189 | 4.91** |

**Note: CCABD-4.08* LCCED=4.91

Table 4. Ratios from actual body data and photo data.

| Parameter | HB/HFL | HFL / HB- HFL | HS- HFK / HFK | HS/HS-HFK | HH1/HS | HS/ HH1-HS |
|-----------|---------------|---------------|---------------|--------------|------------|---------------|
| ratioABD | 1.658 | 1.520 | 1.719 | 1.582 | 1.662 | 1.511 |
| ratioPD | 1.669 | 1.493 | 1.645 | 1.608 | 1.610 | 1.638 |
| Parameter | HB/HBL | HBL/ HB-HBL | HP-HBK/HBK | HP/HP -HBK | HH2/HP | HP/ HH1-HP |
| ratioABD | 1.656 | 1.524 | 1.612 | 1.620 | 1.549 | 1.762 |
| ratioPD | 1.643 | 1.556 | 1.607 | 1.622 | 1.517 | 1.867 |
| Parameter | LWH**/LFH+LBH | LFH+LBH / LSH | HFK/HS | LFH/ LWH | HB-HFL /HB | HFH/ HH1- HFK |
| ratioABD | 1.793 | 1.260 | 0.368 | 0.361 | 0.397 | 0.284 |
| ratioPD | 1.696 | 1.438 | 0.378 | 0.397 | 0.401 | 0.307 |
| Parameter | LWH/LSH+LBH | LSH+LBH /LFH | HBK/HP | LSH/ LWH | HB-HBL /HB | HBK/HH2- HBK |
| ratioABD | 1.563 | 1.773 | 0.383 | 0.442 | 0.396 | 0.328 |
| ratioPD | 1.658 | 1.519 | 0.384 | 0.410 | 0.391 | 0.338 |
| Parameter | HB/HS | HH1/ HH1- HFK | HS/HFL | HH1**/HB | | |
| ratioABD | 1.383 | 1.284 | 1.199 | 1.202 | | |
| ratioPD | 1.341 | 1.307 | 1.245 | 1.200 | | |
| Parameter | HB/HP | HH2/ HH2-HBK | HP/HBL | HH2**/HB | | |
| ratioABD | 1.305 | 1.378 | 1.269 | 1.187 | | |
| ratioPD | 1.335 | 1.338 | 1.284 | 1.186 | | |
| Parameter | HH1-HFL/HFL | LFH / LSH | WFP/WH P | LFP/LHP | HFL/HBL | WS/ WP |
| ratioABD | 0.992 | 0.815 | 1.185 | 1.113 | 0.999 | 1.092 |
| ratioPD | 1.005 | 0.968 | — | — | 0.984 | — |
| Parameter | HH2- HBL/HBL | HFH/FSH | WFP/ LFP | WH P /LHP | HFK/HBK | HS/HP |
| ratioABD | 0.966 | 1.076 | 1.00 | 0.94 | 0.906 | 0.943 |
| ratioPD | 0.949 | 1.078 | — | — | 0.940 | 0.954 |
| Parameter | HH1/HH2 | HH1/HFL | HFL/ HFK | HH1/HH1-HFL | HH1/HFK | HB/ HFK |
| ratioABD | 1.012 | 1.992 | 2.268 | 2.013 | 4.519 | 3.760 |
| ratioPD | 1.012 | 2.005 | 2.125 | 1.995 | 4.259 | 3.547 |
| Parameter | | HH2/HBL | HBL/ HBK | HH2/ HH2-HBL | HH2/HBK | HB/ HBK |
| ratioABD | | 1.966 | 2.058 | 2.035 | 4.047 | 3.408 |
| ratioPD | | 1.949 | 2.029 | 2.054 | 3.954 | 3.334 |

**Note: HH1= HFH+HB; HH2= HSH+HB; LWH= LBH+LFH+LSH

Table 3 shows the estimated data (ED) based on the photo data. The error between the estimated body data and the actual body data was not too

large, so this has important guiding significance for the non-contact measurement of the Bactrian camel body size.

In Table 3, the error between estimated body data and actual body data of bull camel was small, except for the length error of the first hump, which was 10.51%. It is considered as the larger error and is caused by the differences in the measuring position. In addition, $CCABD/LCCPD=4.08\lambda$, which means that the three-dimensional chest circumference of bull camel is as 4λ times as the line chest circumference on bull camel photo.

Considering the ratio combinations of all horizontal line segments and vertical line segments with visual segmentation significance, the following 105 vertical (the heights) ratios and horizontal (the lengths) ratios, 55 ratios belong actual body data and 50 ratios belong photo data, were calculated in bull camel body size data.

It can be seen from Table 4, the actual body data ratios and the corresponding photo data ratios have very similar values, and have interesting ratios, such as φ , 2φ , $1-1/\varphi$, $2-1/\varphi$, 1, 2, 4, and their statistical analysis results are shown in Table 5.

In Table 5, there are 32 ratios (16 for ABD data and 16 for PD data) with a mean of 1.611 which is very close to the golden ratio φ and their mean square error (MSE) is 0.013. There are also 16 ratios close to $1-1/\varphi$, 8 ratios close to $2-1/\varphi$, 8 ratios close to $2/\varphi$, and 25 ratios close to 1, 8 ratios close to 2, 8 ratios close to 4, having relatively small MSE. Moreover, the dispersion of the mean of all ratios was very small.

Table 5. Statistical analysis of various ratios.

| | Ratio values | | | | | | | | AVG | SD | MSE |
|-----------------|--------------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|
| φ : | 1.658 | 1.520 | 1.719 | 1.582 | 1.662 | 1.511 | 1.656 | 1.524 | 1.611 | 0.112 | 0.013 |
| | 1.669 | 1.493 | 1.645 | 1.608 | 1.610 | 1.638 | 1.643 | 1.556 | | | |
| | 1.612 | 1.620 | 1.549 | 1.762 | 1.793 | 1.260 | 1.563 | 1.773 | | | |
| | 1.607 | 1.622 | 1.517 | 1.867 | 1.696 | 1.438 | 1.658 | 1.519 | | | |
| $1-1/\varphi$: | 0.368 | 0.361 | 0.397 | 0.284 | 0.383 | 0.442 | 0.396 | 0.328 | 0.373 | 0.039 | 0.002 |
| | 0.378 | 0.397 | 0.401 | 0.307 | 0.384 | 0.410 | 0.391 | 0.338 | | | |
| $2-1/\varphi$ | 1.383 | 1.284 | 1.341 | 1.307 | 1.305 | 1.378 | 1.335 | 1.338 | 1.334 | 0.033 | 0.003 |
| $2/\varphi$: | 1.199 | 1.202 | 1.245 | 1.200 | 1.269 | 1.187 | 1.284 | 1.186 | 1.222 | 0.036 | 0.002 |
| 1 | 0.992 | 0.815 | 1.185 | 1.113 | 0.999 | 1.092 | 0.999 | 1.092 | 1.000 | 0.076 | 0.006 |
| | 1.005 | 0.968 | — | — | 0.984 | — | 0.984 | — | | | |
| | 0.966 | 1.076 | 1.00 | 0.94 | 0.906 | 0.943 | 1.012 | — | | | |
| | 0.949 | 1.078 | — | — | 0.940 | 0.954 | 1.012 | — | | | |
| 2 | 1.992 | 2.268 | 2.013 | 1.966 | 2.058 | 2.035 | — | — | 2.041 | 0.0082 | 0.008 |
| | 2.005 | 2.125 | 1.995 | 1.949 | 2.029 | 2.054 | — | — | | | |
| 4 | 4.519 | 3.760 | 4.259 | 3.547 | 4.047 | 3.408 | 3.954 | 3.334 | 3.854 | 0.391 | 0.175 |

Discussion

It is evident from Table 1 and Table 2 that the body size data of Gobi Red Bull camel possess a small dispersion, which means that the bull camels selected by the herders based on long-term nomadic production experience (Dongjirzhab, 2019) are more consistent in appearance and size, and it indicates that the data analysis method used in this study is relatively stable. As shown in Table 3, the error between the actual body data of bull camel and estimated body data based on bull camel photos is small enough to prove the reliability of the calculation method of extracting actual body size from photos, can provide a theoretical basis for the non-contact measurement of Bactrian camel body size measurements. The golden ratio φ has many magical characteristics, such as $\varphi=1+1/\varphi$, $\varphi^2=1+\varphi$ and so on (Gary, 2018; Thapa and Thapa, 2018). In Table 5, there are 32 ratios are very close to the golden ratio φ , and 32 ratios contain $1/\varphi$. The appearance of these golden ratios φ may not be accidental, and may indicate the natural mystery inherent in the body morphology of the Bactrian camel.

Conclusion

In present study, 21 actual body size parameters and corresponding photo data of bull camel were measured. The error between the estimated body data from the photo data and the actual body was relatively small. The three-dimensional chest circumference of bull camel is 4λ times as the line chest circumference of bull camel photo. Many related golden ratio φ was found in Bactrian camel body size

data ratio. And an optimised formula for estimating the weight of bull camel based on photo data was derived.

In short, the bull camels selected by the herders based on long-term nomadic production experience are more consistent in appearance and size, and the calculation method of extracting actual body size from photos is reliable. It can provide a theoretical basis to the non-contact measurement of Bactrian camel body size and weight.

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