

Accuracy of Image Analysis for Linear Zoometric Measurements in Dromedary Camels

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Abstract

The present study consisted in verifying the effectiveness of the image analysis method for body measurement in dromedary camel compared to manual measurements as a reference method. To do this, twenty-one linear body measurements were estimated on 59 adult Sahraoui dromedary camels (22 males and 37 females) with normal clinical condition by the standard method using a measuring stick or vernier caliper. Image analysis on profile, front or behind photographs were processed using Axiovision Software. Overall; mean comparison, relative error, variance, Pearson's correlation coefficient and coefficient of variance showed that the image analysis method is accurate in relation to the manual measurement. Furthermore, image analysis results indicated relevant accuracy (bias correction factor, $C_b \approx 1$) and precision (Pearson $\rho \approx 1$) which were significantly correlated with the results of the reference method (Lin's concordance correlation coefficients $r_{ccc} \approx 1$). According to Blant Altman upper and lower limits of agreement, the concordance was estimated between 93.22 and 98.3%. Passing-Bablok regression showed good relationship between results of the two methods displaying no significant systematic and proportional bias. The image analysis method for linear body measurements in dromedary camel yielded results that are in agreement with the manual measuring method. This method is a valid tool for studies on camel conformation traits.

Introduction

At the outset of genetic studies at the beginning of the last century, they started with morphological characters, but with time and technological development, these markers can gradually lose their importance to the detriment of biochemical markers and then molecular markers. However, with the advent of molecular biology techniques of next generation sequencing (NGS) and the possibility of identifying genomic regions related to phenotypes of interest by genome-wide association study (GWAS), morphological markers have regained the forefront of the scientific scene. In addition, they are increasingly being implemented for animal research and health diagnosis and production management. That said, collecting this information is not always easy and requires heavy investigation, especially for wild animals (e.g., feral camels) or those that live in pastoral systems with permanently accessible grazing, like camels which lead to more challenges for standardizing classic measurement collection protocol (Alhajeri et al., 2021).

The use of new technologies has given rise to a new type of farming, "precision farming", which can be defined as "the coordinated use of behavioral, physiological, and/or production parameters and information and communication technologies (ICT) to exchange, store, transform, and return this information to help with decision-making (Allain et al., 2014). Among the emerging technologies is image analysis, which is obtained by photography, video processing, thermography or thermal image processing, 3D body scanners, mobile body scanning, etc. Imaging (2D) with the use of devices allowing the capture and analysis of shapes which enable mainly to carry out body measurements and access new indicators by geometric morphometric, such as functional morphological indexes, body condition evolution and shape variation of foot pads, with minimal direct contact with different animal categories

(Al-Atiyat et al., 2016; Alhajeri et al., 2021). Some challenges arise when working with live camels and taking measurements related to skull bones, the uro-genital region, or when taking measurements in a crouch position close to the ground, which may frighten the animal, which may become restless and kicking or stepping on the worker. The measurements close to the face, especially from males during rutting season, can expose them to bites (Yahaya et al., 2012; Ayadi et al., 2016; Gherissi et al., 2018; Alhajeri et al., 2021). Image analysis was also used to behavior monitoring, lameness and posture defectuosity diagnosis in other species (Viazzi et al., 2013; Kashiha et al., 2014; Zhao et al., 2015; S n que et al., 2019; Kang et al., 2020).

Our work presents an investigation to verify the effectiveness of distance-based linear body measurements in dromedary camel using an image analysis approach compared to manual measurement, considered as the reference method, and therefore, the possibility to give for researchers and camel breeding practitioners an important tool to lighten camel handling in order to take body measurements.

Materiel And Methods

Animals

The study was conducted between February 2019 and August 2020 on randomly selected 59 Sahraoui dromedary camels (22 males and 37 females) with normal clinical condition (mean age= 9 ± 3.56 years, mean body weight = 452.10 ± 98 kg measure by Kamili et al (2006) formula: Live weight (kg) = $4.06 \times \text{Age (year)} + 3.05 \times \text{CN (cm)} + 3.38 \times \text{TC (cm)} + 1.38 \times \text{HL (cm)} - 191$; With 94% of the explained variance, where CN is the circumference of the neck at the middle of the neck, TC is the thigh circumference at the middle of the thigh and HL is hump length.

Manual body measurement

The animals come from sedentary camel herds in the region of El Oued in the south-east of Algeria. Twenty-one linear body measurements to the nearest centimetre were performed for each animal from the left side of the camel and in a standardised position, according to descriptions given by Alhajeri et al. (2021) (Fig 1). These measurements were taken manually using a measuring stick or vernier caliper and were considered as reference measurements. Long linear measurements, such as body length, were taken with assistance from a second evaluator.

Animal photography and image processing

The setting, the camel's position, and the camera's distance are all important considerations. The place for image collection was chosen since it was open and flat. The camera was positioned at a standardized height of 1.2 m on a camera stand 3 m away from the camel center of balance. This distance and height allowed the animal's body to be properly framed. We draw standard lines on the ground before starting

photo taking for each animal in order to position the animal in the right place and keep him the same distance from the camera.

The images used for this study were obtained using a digital camera (Sony DSCW830 Compact) in standard mode (resolution of 4,912 x 1,080 / 3,424 x 1,920 and a focal length of 4.5 to 36 mm). The location of the photos should be well lit and the camel's coat color contrasted well with the animal's background to better target the different anatomical points used in the measurements. A 1 m ruler is placed near the animal on the same midline of the body to be used for calibration of distances on the computer measurement software. Obtaining Portable Graphics Format (PNG) images from the photos taken will compress the image background into a very small size because the content of the pixel is identical. Anatomical reference points for calibration were placed on the animal's body in the following places (Fig 2): tip of the nose, base of the head, base of the neck, point of the shoulder, point of buttock, point of withers, point of the hump, points of ilium, point of ischium, trochanter, elbow, knee, hock and front and rear fetlocks. The photos are taken when the animal is in a static position, in an upright position, head raised in a natural position, in three planes perpendicular to the camera: profile left, front and behind (Fig 1a, b, c). The obtained images were processed manually using Axiovision Software Rel 4.6 (Carl Zeiss, Thornwood, NY). The measurements of the various linear parameters by drawing a straight line between two points are obtained in pixels and are automatically converted by the previously calibrated software (Gherissi et al., 2020).

Statistical analysis

MedCalc Statistical Software Ltd, version 20.019 Ostend, Belgium was used for descriptive statistics, Concordance correlation analysis, Passing-Bablok regression analysis, and the Bland-Altman method to determine agreement between the image analysis method and the reference body measurement method.

The descriptive statistic was used to determine the mean of each parameter according to the measurement method employed, as well as the mean of the two methods, variance, relative error of variance, and Pearson correlation coefficient. The difference in the means between the measurements of each parameter was carried out using the t-test for independent sample analysis with a significance level of 0.05 (5%) or lower.

Lin's concordance correlation coefficient (rccc) generate the precision (Pearson's ρ) and accuracy (bias corrected factor, Cb) and was used as an indicator for the strength of concordance between measurements. Accuracy refers to the ability to measure a body measurement close to its true value, whereas precision refers to the spread of repeated measurements. The values ≥ 0.99 , 0.95-0.99, 0.90-0.95, and ≤ 0.90 reflect perfect, substantial, moderate, and poor agreement, respectively.

Passing-Bablok regression test was applied to generate the regression equations and estimate the constant, proportional, and random bias by interpreting the intercept, slope, and residual standard deviation (RSD) values using the 95% CI for each case.

Bland-Altman test was carried out by plotting the difference between the two compared body measurements against the mean of the two measurements. This method evaluates the agreement between the two measurement methods instead of validating the experimental method against the reference method. As a measure of precision, the 95% limits of agreement were admitted.

Results

The proposed method was accurate ($v^2 = \pm 0.045\%$), strongly correlated with the reference method ($r > 0.997$, $P < 0.001$), and had low coefficient of variation ($CV < 3.80\%$) (Figure 3).

The body measurements obtained by the digital image analysis were very accurate in relation to reference values (Table 1). Eleven of twenty-one body measurements obtained by the digital image analysis method were very accurate in relation to reference values ($P \geq 0.05$): TL, SIL, HW, HH, WT, IsW, CD, LPL, NL, HuL and HuW with a respective mean of: 327.615 cm, 134.18 cm, 171.99 cm, 189.85 cm, 41.93 cm, 25 cm, 71.51 cm, 152.99 cm, 80,71cm, 49,68 cm, and 26,75. Compared to the reference method, the proposed method underestimated LPL (-1.23cm) and NL (-0.36cm) but it overestimated the following parameters: TL (1.17cm), SIL (+0.3cm), HW (+0.91cm), HH (+0.29cm), WT (+0.29cm), IsW (+0.12cm), CD (+0.36cm), HuL (+0.52cm), HuW (+1.97cm). Moreover, the CV of the parameters WT, IsW, CD, NL, HuL, and HuW is relatively high (3.46 to 5.97%). The determination of the other parameters: HR, IW, SW, LAL, NW, HuH, LH, HeW, EL, and TAL by the two measurement methods revealed that they are significantly different ($p = 0.02$ to 0.000) and the CV is between (2.77 and 8.48%). The scatter plots of these parameters showed how the data was plotted for each method (Sup. figures 01).

Table 1

Linear body measurements of camels ($n = 59$), relative error (RE), relative error of variance (v^2), and Pearson's correlation coefficient (r) between reference and image analysis results.

Variable	Reference method	Image analysis	Mean	RE	v^2	r	CV (%)	P-value
TL	327	328.23	327.615	-1.17	-5.44	0.978	1.71	0.2535
SIL	134.03	134.33	134.18	-0.22	-1.75	0.984	1.62	0.4722
HW	171.54	172.45	171.995	-0.53	-2.66	0.974	1.56	0.0571
HH	189.71	190	189.855	-0.15	8.89	0.962	1.58	0.4817
HR	168.17	170	169.085	-1.09	-8.60	0.929	3.29	0.0067
IW	28.1	28.71	28.405	-2.17	-31.45	0.879	4.82	0.0125
WT	41.79	42.08	41.935	-0.69	-16.48	0.926	3.7	0.3117
IsW	24.94	25.06	25	-0.48	-11.87	0.924	5.16	0.6173
CD	71.33	71.69	71.51	-0.50	-22.05	0.951	3.46	0.4451
SW	42.71	43.42	43.065	-1.66	5.36	0.943	3.75	0.0127
LAL	144.35	142.16	143.255	1.52	-8.40	0.934	3.11	0.0021
LPL	153.61	152.38	152.995	0.80	-4.15	0.958	2.45	0.0628
NL	80.89	80.53	80.71	0.45	-0.05	0.938	3.61	0.5078
NW	25.62	26.07	25.845	-1.76	-4.49	0.922	4.32	0.0257
HuH	20.96	21.73	21.345	-3.67	-20.42	0.938	7.12	0.0035
HuL	49.42	49.94	49.68	-1.05	-4.16	0.962	3.82	0.1135
HuW	25.77	27.74	26.755	-7.64	-22.66	0.943	5.97	0.8918
LH	51.2	50.27	50.735	1.82	-9.02	0.817	2.77	0.0001
HeW	22.76	23.74	23.25	-4.31	8.44	0.793	5.86	0.0033
EL	12.3	11.74	12.02	4.55	66.35	0.272	8.48	0.0034
TaL	66.61	64.62	65.615	2.99	1.39	0.958	4.69	0.0001

TL: Total body length; SIL: Scapular ischial length ; HW: Height at withers; HH: Height at the hump; HR: Height at rump; IW: Bi-iliac width; WT: Width at trochanter; IsW: Bi-ischial width; CD: Chest depth ; SW: Width of the shoulders; LAL: Length of the anterior limb; LPL: Length of the posterior limb; NL: Neck length; NW: Neck width; HuH: Hump height; HuL: Hump length; HuW: Hump width; LH: Length of the head; HeW: Head width at occipital level; EL: Ear length; TaL: Tail length

The concordance analysis between the image analysis and the reference method for the body measurements of the studied camels was carried out by interpreting the Lin's coefficient. Table 02 shows the results for all studied variables, and the graphical presentation of the results is reported in supplementary figures (2), which display the graphs for the other variables. It is easy to see that the image analysis provides results which are perfectly in agreement with the reference method for LT justified by a positive Lin correlation coefficient close to 1 and confirmed by a close Pearson and C_b correlation coefficient close to 1. A similar finding was obtained for all other studied parameters except for ear length (EL; Lin coefficient = 0.269, Pearson coefficient = 0.346, C_b = 0.779).

Table 2

Concordance correlation analysis between the body measurement methods (Reference method and image analysis method; n =59).

Variable	Lin's r_{ccc} (95%CI)	Precision p	Accuracy C_b
TL	0.987 (0.978 to 0.992)	0.988	0.999
SIL	0.991 (0.984 to 0.994)	0.991	0.99
HW	0.987 (0.978 to 0.992)	0.988	0.999
HH	0.988 (0.980 to 0.992)	0.989	0.998
HR	0.9668 (0.944 to 0.980)	0.967	0.999
IW	0.936 (0.896 to 0.961)	0.944	0.991
WT	0.927 (0.882 to 0.955)	0.931	0.995
IsW	0.948 (0.915 to 0.968)	0.95	0.998
CD	0.95 (0.92 to 0.969)	0.956	0.994
SW	0.936 (0.896 to 0.961)	0.943	0.993
LAL	0.969 (0.949 to 0.981)	0.974	0.994
LPL	0.976 (0.960 to 0.985)	0.977	0.998
NL	0.964 (0.940 to 0.978)	0.964	0.999
NW	0.941 (0.903 to 0.964)	0.945	0.994
HuH	0.947 (0.917 to 0.968)	0.959	0.988
HuL	0.980 (0.9679 to 0.9884)	0.981	0.999
HuW	0.952 (0.922 to 0.970)	0.956	0.994
LH	0.954 (0.925 to 0.972)	0.964	0.989
HeW	0.792 (0.678 to 0.869)	0.816	0.97
EL	0.269 (0.015 to 0.444)	0.346	0.779
TaL	0.947 (0.914 to 0.968)	0.959	0.987
<i>Lin's concordance correlation coefficients (r_{ccc}) with 95% confidence intervals (95% CI), precision (Pearson p) and accuracy (bias correction factor, C_b) are reported (See Table1 for variables abbreviation)</i>			

Figure (4) represents the Passing and Bablok regression line, illustrating the correlation existing between the measurement of the total length (N = 59) by the reference method (TL_R) and image analysis (TL_IA).

The equation for the regression line is as follows: $TL_IA = -5.66 + 1.024 TL_R$ with CI 95% of the systemic difference = -19.21 to 5.26 and CI95% of the slope = 0.96 to 1.03 and $R^2 = 0.95$ ($P < 0.0001$). Data were plotted near the equality line and CI95% of the y-intercept of the slope reveals that there is no systematic difference (0 located outside the CI95% of the y-intercept) or proportional difference (1 located outside the CI95% of the slope) between the two means of measurement. Reference and estimated methods produced accurate results for all the morphological parameters studied, with the main observations of no significant systematic difference [-7.31; 9.61] and a proportional difference which goes from 0 to 21% (Sup. figures 3). Furthermore, only the EL study showed high systematic and proportional bisection values of around 7.66 cm and 67%, respectively (Sup. Figure 3).

Figure 5 represents the results of the Bland-Altman for comparison between the reference method and image analysis for the camel's total length (TL). The Bland-Altman analysis diagram and the calculation of agreement limits show that the average of the differences in TL is $d = 1.16$, measured by each of the two methods. The agreement limits = [-14.1; 16.43]. TL_IA turns out to be a little higher than TL_R. The differences in the measurements of two samples are situated above the upper agreement limit and one sample is below the lower agreement limit, giving a concordance of 94.91% (Figure 5). By observing the results of the rest of the morphological parameters, we find that there is no bias between measurements and the narrow limits of agreement for LH. For the rest of the variables, there is usually a low bias between measurements and narrow limits of agreement concordance ranging between 93.22 and 98.3% (Sup. figures 4).

Discussion

While new body measurement technologies are making great advances in certain species, such as cattle (Negretti et al., 2008; Bewley et al., 2008; Fischer et al., 2015; Kuzuhara et al., 2015; Le Cozler et al., 2019; Ruchay et al., 2020; Kojima et al 2022), they are still in full development in equines (Freitag et al., 2021), pig (Schofield et al., 1999; Zhang et al., 2021), sheep (Zhang et al., 2018a, b) and also bees (Khedim et al., 2021; Benghalem et al., 2021). However, this method is all at the beginning of experimentation in the camel species, which is still exploited mainly in traditional systems (Iglesias et al., 2020; Çağlı and Yılmaz 2021). Access to morphological evaluation using image analysis in this species is of particular interest because of difficulties in handling and restraining, its large size and mobile or even aggressive behavior (Iglesias et al., 2020; Alhajeri et al., 2021). Body measurements in these species require one to two people to immobilize the animal and two other people to take body measurements (Meghelli et al., 2020). Using the manual method is very time-consuming and is not without risk for the handlers and the animal. Indeed, this technology would be highly recommended to assess camels' morphological changes and body condition during the different stages of lactation and also to determine the conformation, the profile, and the format of camels intended for slaughter or the monitoring of young animals in growth. Finally, this technology is also interesting for determining the animals' live weight when prescribing drugs or calculating individual needs when formulating rations.

The present study investigates the effectiveness of the image analysis method by checking the hypothesis that this method offers a fine, precise, non-subjective analysis of linear body measurement in dromedary camels. To do this, we tried to determine the relative error of variance, concordance correlation, and possible sources of bias in the results of the two methods for each parameter. The morphological criteria take the animal into consideration in its length, width, height, and depth by examining the images taken from the profile, front, and behind positions.

Linear regression between all the measurements taken by the reference method and those obtained by image analysis revealed a significant high R^2 ($P < 0.001$) and a coefficient of variation (VC) of less than 10%. This indicates that the results of the two methods are quite correlated. However, high correlation does not necessarily mean agreement since the correlation coefficient cannot detect systematic bias (McAlinden et al, 2011). A non-significant difference in the mean values between the two body measurement methods was recorded for eleven parameters ($P > 0.05$). The VC is calculated as an indicator which quantifies the variability of a quantitative characteristic measured several times compared to the mean of this characteristic calculated from these same measurements. Recently; Çağlı and Yılmaz (2021) have compared the body measurements between manual measuring method and photographic and 3D methods in dromedary species. These authors showed that the 3D method is a more reliable, easy, and practical method for body measurements. The accuracy of image analysis compared to manual measurements was lower, indicated by a significant difference between the results of the two methods for height at withers, back height, rump height, body length, shoulder width, and rump width (Çağlı and Yılmaz 2021). According to these authors, only rump width was statistically non different between the two methods (Çağlı and Yılmaz 2021). These results are different from ours except for shoulder width. In addition, we have found that the results of the following parameters are statistically no different: chest depth, width at the trochanter, length of the posterior limb, neck length, hump length, and hump width. When using 3D technology for zoobiometry in dromedary camels, Çağlı and Yılmaz (2021) found that there was a significant difference between the 3D analysis method and manual measurements only for two parameters, which are brisket height and abdominal height. Differences between our results and those obtained by Çağlı and Yılmaz (2021) would be due to the image analysis process. On the other hand, the results obtained by Fischer et al. (2015) and Le Cozler et al. (2018) on cattle indicate that the measurements using a photographic support provide good precision (correlation between 0.78 and 0.89 for the chest depth, hip width, and circumference chest) and also good repeatability and reproducibility ($CV_r = 2.91\%$ and $CV_r = 3.95\%$, respectively) except for ischial Width, where both Ingenera and Morpho 3D devices do not give reliable results for this parameter (Le Cozler et al. 2018). Nowadays, analyses of the repeatability and reproducibility of zoobiometry on photographic images in dromedaries are non-existent.

Furthermore, the mean comparison and variation coefficient level of manual measurements and image analysis should be taken with caution as they don't provide proper conclusions. Indeed, the two averages can be equal to two completely discordant series. It compares the means of two samples, and the results will reveal a constant but not proportional difference between the two sets of measurements (Bilić-Zulle 2011). The $VC < 10\%$ does not necessarily indicate that the N values measured on an individual are close

to each other. Likewise, the correlation between the values of two different methods could be significantly high, but the two methods are not concordant. Correlation describes the linear relationship between two sets of data but not their agreement (Udovičić et al., 2007); it does not detect if there is a constant or proportional difference between the two methods. Linear regression presumes that comparative method results are measured without error (Linnet 1993). Therefore, it is more appropriate to analyze the correlation between these methods using Lin's concordance method on individuals measured only once by the same operator to determine agreement between methods (Lin 1989; Barnhart et al., 2007). Furthermore, the graphical method of Bland and Altman was used because it is based on the definition of the concordance between two series of measurements (Bland and Altman, 1986). The two series are concordant if one doesn't overestimate or underestimate the other significantly. The Bland-Altman analysis enables the determination of systematic bias between manual measurement as a reference method and an image analysis method by calculating the mean difference between measurement results. It allows the calculation of limits of agreement, which allows the estimation of the total bias consisting of systematic and random bias (Bland and Altman 1986; Bland and Altman 1999). We found some studies that used such data analysis methods to describe agreement between methods to evaluate body measurements, claw conformation, udder traits, and body composition in dairy cattle automated devices (Alawneh et al., 2011; Song et al., 2014; Laven et al., 2015; Bell et al., 2018; Shorten 2021). However, we didn't find such analysis for body measurement using different methods in camel species. Furthermore, similar approaches were used to estimate the concordance to predict body fat percentage and body mass index categories in humans using different methods and devices (Affuso et al., 2018; Kogure et al., 2020; Lahav et al., 2021).

In our study, we observed a perfect level of Lin's coefficient of concordance for all morphological parameters except EL. This indicates that the differences between the abscissa (image analysis method) and ordinate (reference method) points and the 45 ° line (line of equality) are small, which is represented by Cb values (accuracy) close to 1 (Sup. Figures 2). It was also observed that there is usually a low bias between measurements and narrow limits of agreement concordance ranging between 93.22 and 98.3% (Sup. figures 2). Since measurement errors had to be assumed in both comparison and testing methods, the Passing-Bablok regression was preferred over ordinary linear regression (Passing and Bablok 1983). Passing and Bablok regression analysis allows valuable estimation of the analytical methods' agreement and possible systematic bias between them. It is robust and non sensitive to the distribution of errors and data outliers (Bilić-Zulle 2011). Reference and estimated methods produced accurate results for all studied morphological parameters. Based on the reported 95% limits of agreement, the slope reveals that there is no systematic difference [-7.31; 9.61] and also no proportional difference (from 0 to 21%) between the two means of measurement (Sup. figures 2). Only the EL study showed high systematic and proportional bisection values of around 7.66 cm and 67%, respectively (Sup. Figure 3). Based on similar data analysis, Zhang et al. (2018a) indicated that the method based on visual image analysis is effective, and it is especially suitable for sheep feeding in an intensive and large scale way.

The results have shown that the use of image analysis as a method of measuring linear body measurements using photos taken from profile, front, and behind positions allowed us to obtain results

with low coefficients of variation and high correlation apart from the ear length. All statistical analyses confirmed a very good concordance between the two series of measurements, with low bias and no systematic or proportional difference between the two measurement methods.

Our study has clearly shown that, by the numerical method, nearly all the measurements can be estimated with precision. These results indicate that the image body measuring method is easier to implement than the manual method and also has the advantages of less workload and impersonal impartiality at high speed while working in safety, especially in difficult conditions. The next step of our study would be to improve the conditions for taking photos so we could get a better magnification of the technique.

Declarations

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions: G.D.E. conceived and designed the study and performed the experiments; G.D.E., L.R. analyzed the data and G.D.E., L.R., C.F. and G.S.B.S. wrote and corrected the paper. All authors read and approved the manuscript.

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Ethics declarations: The camels were studied according to the ethical principles of animal experimentation and international guidelines for animal welfare (Terrestrial Animal Health Code 2018, section 7. Art 7.5.1) and national executive decree No. 95-363 of November 11, 1995 (Algeria).

Consent to participate: Not applicable.

Consent for publication: Not applicable.

Competing interests: The authors declare that they have no conflict of interest.

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Figures

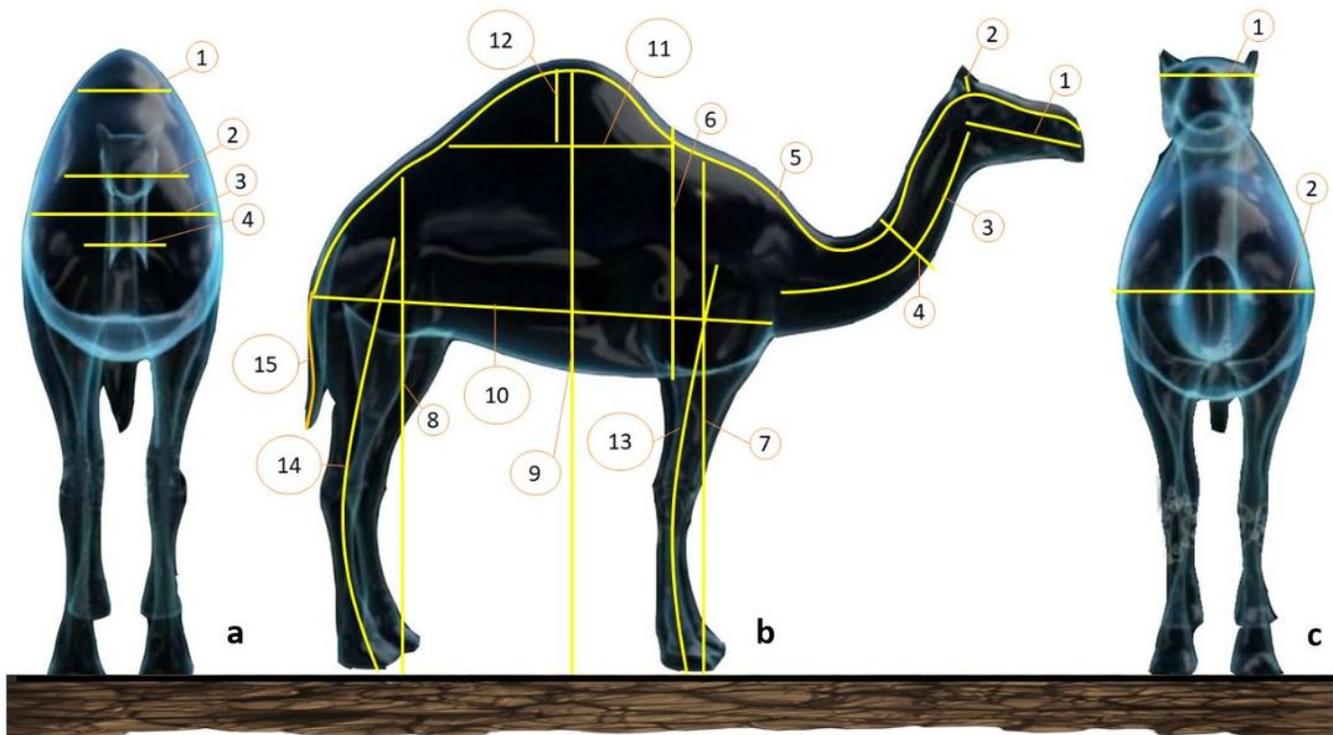


Figure 1

Linear variables used to validate an image analysis method for determination of camel body measurements. Definitions of the measured body dimensions: a- Behind position: 1- Hump width (HuW), 2- Bi-iliac width (IW), 3- Width at trochanter (WT), 4- Bi-ischial width (IsW). b- Profile position: 1- Length of the head (LH), 2- Ear length (EL), 3- Neck length (NL), 4- Neck width (NW), 5- Total body length (TL), 6- Chest depth (CD), 7- Height at withers (HW), 8- Height at rump (HR), 9- Height at the hump (HH), 10- Scapular ischial length (SIL), 11- Hump length (HuL), 12- Hump height (HuH), 13- Length of the anterior limb (LAL), 14- Length of the posterior limb (LPL), 15- Tail length (TaL). c- Front position: 1- Head width at occipital level (HeW), 2- Width of the shoulders (SW)



Figure 2

Diagram showing profile standard position of the camel ready to be photographed and calibration markers.

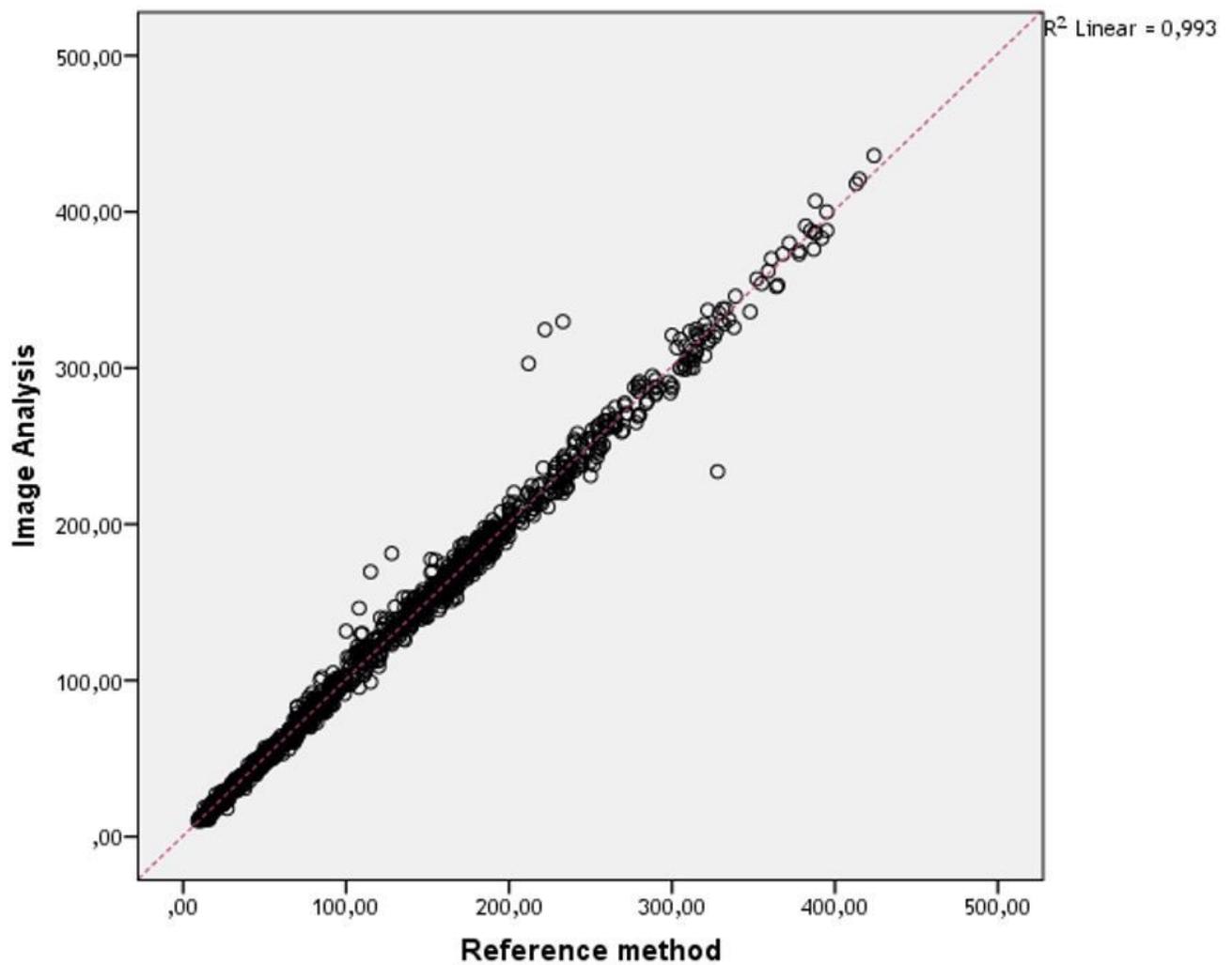


Figure 3

Relationship between camel body measurements obtained by image analysis and the reference method. The dashed diagonal line is the equality line, where $y = x$. Statistics: Reference method = 104.81cm; Image analysis = 105.57 cm; mean = 105.19cm, $y = 1.002x - 0.596$, $R^2 = 0.993$, $r = 0.997$, $P < 0.001$, CV = 3.80%.

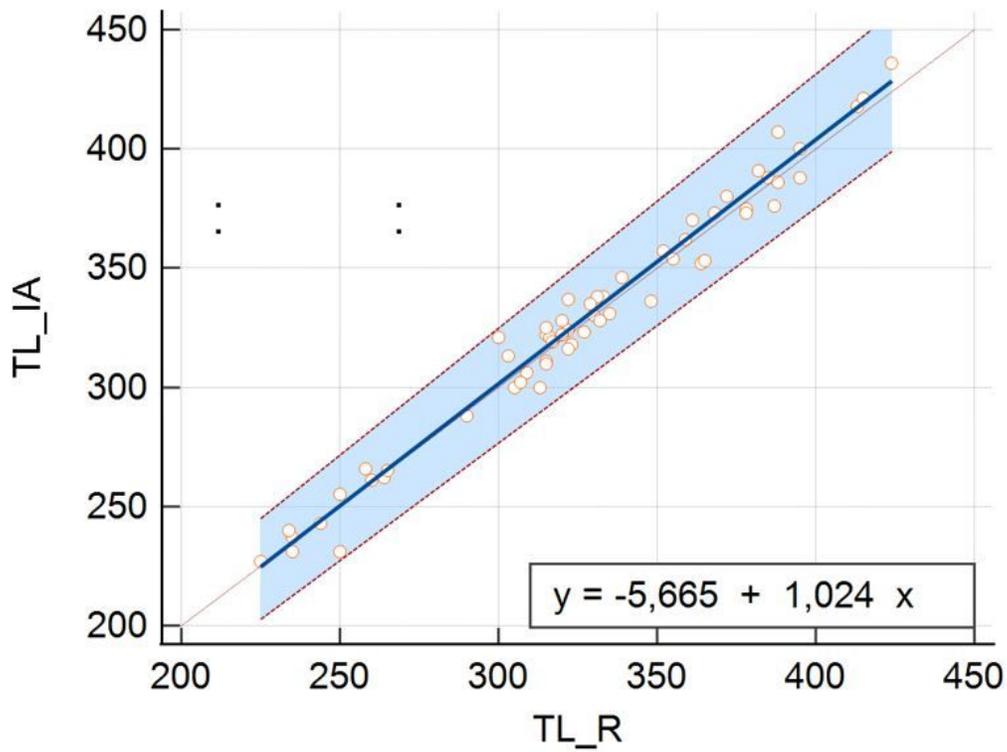


Figure 4

Passing-Bablok regression for analysis of relationship between camel spiral circumference obtained by reference method (TL_R) and image analysis (TL_IA). The blue diagonal line indicates the equality line, where $y = x$. Statistics: TL_R= 327.06cm; TL_IA = 328.23 cm; mean = 327.64 cm; SEM = 6.57, Intercept= -5.66 (95% CI= -19.21 to 5.26), Slope= 1.024 (95% CI=0,96 to 1,03), $R^2 = 0.95$, $P < .0001$, CV = 1.71%.

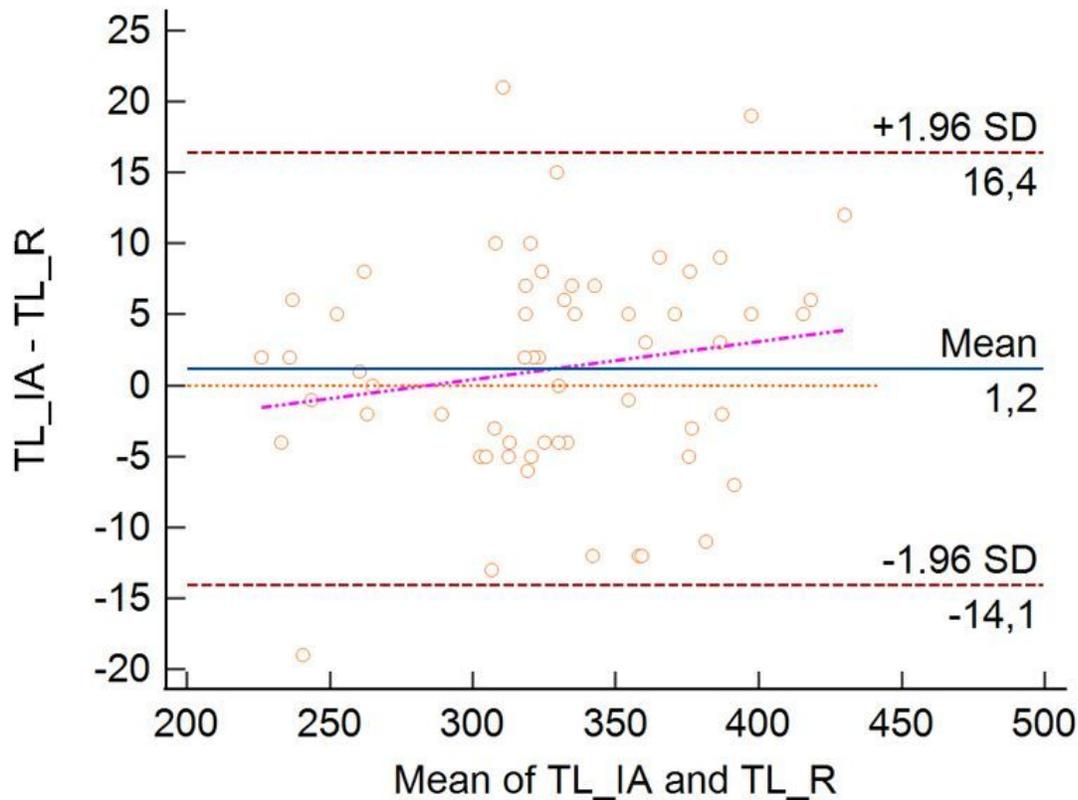


Figure 5

Bland-Altman plot analysis for comparison of Total Length (TL) obtained by reference method (TL_R) and Image analysis (TL_{IA}). The dashed lines are upper and lower limit of agreement, the solid line is the mean difference (bias). Statistics: Mean difference = 1.16 (95% CI=-0.86 to 3.19); P (H₀: Mean=0): 0.25; Lower limit= -14.1 (95% CI=-17.58 to -10.60); Upper limit =16.43 (95% CI=12.94 to 19.92).

Supplementary Files

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