Determination of some body measurements of camels with three-dimensional modeling method (3D)

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Abstract

In this study, the use of the three-dimensional modeling method was tested in taking some body measurements in camels with a practical method and was compared with other measurement methods. As the animal material of the study, 12 single-humped dromedary female camels and 14 double-humped Camelus dromedarius × Camelus bactrianus: F1 male camels, a total of 26 camels, were used in three camel farms in Incirliova district of Aydın province. The body measurements are taken from each animal by using different three methods, namely by the manual method (MM), by the photography method (PM), and by the three-dimensional modeling method (3D) were the withers height (WH), the back height (BH), the rump height (RH), the body length (BL), the brisket height (BRH), the abdominal height (AH), the shoulder width (SW), and the rump width (RW), and these values were compared with each other. As a result of this study, the mean values of MM and 3D measurement values were very close to each other and the difference between them was found to be statistically insignificant (\( P < 0.05 \)). The difference between the means of PM and MM/3D measurement values was found to be significant (\( P < 0.05 \)). In the measurements taken by MM, 3D, and PM methods in male camels, the values obtained by MM and 3D methods for WH, BH, RH, BRH, AH, BL, and SW were very close to each other and the differences between them were found insignificant statistically (\( p < 0.05 \)). On the determined regression graph, a linear was found between MM and 3D measurement values. As a result of this study, it has been determined that the 3D modeling method can be used as a remote and more practical method in determining the morphological features of large-scale animals such as camels more reliably, more easily, and more practically.

Keywords Dromedary camel · Hybrid camel · Three-dimensional modeling (3D) · Body measurements

Introduction

It is important to determine or to measure the morphological characteristics in defining species and the breed within those species. Morphological characteristics are difficult to determine in farm animals. Besides, estimation of some physiological characteristics is difficult and time-consuming for researchers and breeders in animal breeding studies. All these difficulties have created problems in the work of researchers. Studies have attempted to estimate the characteristics of populations or the identification of breed from these criteria by taking measurements on a small number of animals. The use of body measurements technically and scientifically in the evaluation and breeding of farm animals at the end of the last century has further increased the importance of the subject (Zehender et al. 1996). Studies have been carried out for many years to develop practical and easily applicable methods to define morphological features and especially body measurements and to determine some physiological features in many animals (Wu et al. 2004; Tasdemir et al. 2011; Ozkaya, 2012).

In recent years, scientific studies on the use of digital technology in livestock for these purposes have gained importance. It was stated by Le Cozler et al. (2019) that the three-dimensional (3D) imaging method can be used to monitor the morphology and growth of dairy cows and to estimate indicators such as body volume, surface area, and body weight. Kalkoohi investigated the possibility of
estimating the weight of camels using the digital image processing method and stated that this method could be a good alternative to weighing camels using a scale (Meghelili et al. 2020).

External appearance features are used as important selection criteria in all countries where systematic breeding programs are implemented. Knowing the body measurements of the animals provides convenience in determining the level of feed efficiency and health status of the animal and it is also useful in breeding animal selections (Şekerden and Özkütük 1990; Şekerden and Tapkı 2003). Various body measurements such as body height, rump height, body length, chest depth, withers height, chest width, and circumference are the leading most important morphological characteristics used to determine the individual identities of animals, their structural capacities, their relationships with their yield levels, their morphological type assessments, and most importantly for the registration of breeds (Tien and Tripathi 1990; Velea et al. 1991). The use of digital technology is increasing day by day in animal husbandry as in every field. Efforts have intensified for the use and development of digital technology in different livestock sectors such as faster and easier animal breeding, animal nutrition and welfare, production and processing of animal products, and marketing. Especially with Agriculture 4.0, developed European countries attach importance to digital and robotic developments and smart agriculture practices (Özdogan et al. 2017; Ozsoylu, 2017).

Camel wrestling, located in 8 provinces on Turkey’s western coast, has traditionally been held for many years. Although Dromadary camels were used in wrestling in the past, today wrestling is held between Camelus Dromedarius × Camelus bactrianus F1 male camels called “Tulu” (Manav and Koç 2018; Koç et al. 2018). Camels that are bred for milk, for meat, and for mount in the world, are bred in Turkey for camel wrestling and for prestigious purposes. Camel breeding is done in the west of Turkey for mainly prestige purposes. In recent years, although they are in small numbers, some breeding enterprises have started to breed camels for meat and milk production purposes. As in the world in general, sufficient studies have not been conducted in Turkey towards the identification of morphological and physiological characteristics of camels. In our country, it is necessary to define the morphological and physiological characteristics of both wrestling camels and camels whose breeding and production are desired. Too few researches have been conducted in Turkey to determine the morphological and physiological properties of wrestler camels (Yılmaz et al. 2013).

In this study, in order to measure the body measurements in camels with a practical method, the possibility of using the three-dimensional modeling method (3D) in camel and in similar cattle breeding where body measurements can be measured very difficultly and inconvenience of the method was tested by comparing it with other measurement methods.

Material and methods

Material

This study was conducted in 3 camel breeding farms in Aydın Province in Turkey. In the study, a total of 26 camels, 12 Camelus dromedarius female camels aged 5–12 years old and 14 F1 hybrid Camelus dromedarius × Camelus bactrianus male camels aged 6–16 years old that were bred by double-humped Bactrian male and single-humped Dromedar female and named as “Tulu” were used.

Methods

In this study, various body measurements of Camelus dromedarius (females), Bactrian × Dromedar F1 hybrid male wrestling camels: (1) by hand, using a measuring stick and tape measure; (2) by the method of photographing using a camera; and (3) using a three-dimensional (3D) camera. It was measured by three different methods and the results were analyzed. Measurements taken with a three-dimensional camera were compared with the other measurements taken by the other two measurement methods.

The body measurements taken were withers height (WH), back height (BH), rump height (RH), body length (BL), brisket height (BRH), abdominal height (AH), shoulder width (SW), and rump width (RW) (Bıyıkoğlu 1973).

Manual method (MM) In the manual measurement method, body measurements were taken from each animal by the researchers using a tape measure and a measuring stick.

Photographing method (PM) In this measurement method, the photographs of the animals were taken with a Nikon D3000 brand camera using a 10 × 10 cm² scale paper as a reference. While a photograph was taken by one person, a second person held the scale paper next to the camel, and it was shot from different angles. A total of three photographs of each camel were taken from the side, front, and back. Body pixel measurements of camels were obtained from the obtained images using Adobe Photoshop CS6 (64 bit) Photoshop program. Pixel measurements determined with the help of a 10 × 10 cm² scale have been converted to centimeters. The following formula was used to determine body measurements from the photographs: body size taken = (10 cm × pixels of body size to be determined)/pixels of the scale paper.
The three-dimensional analysis method (3D). For the three-dimensional analysis in the study, the Structure Sensor 3D scanner was used to transfer the models to the digital environment. With this scanner, objects were scanned in 3D and the data obtained were transferred to digital media in real dimensions. In the three-dimensional analysis method, the shooting was taken by a researcher around the calm and docile camels by turning from a distance of 1 to 2 m and the process was completed in half a minute or 1 min. Behaviorally active and angry animals were kept by the owner and the shootings were completed within the same time. The obtained images were transferred to the Blender software of Autodesk Company and the measurements were evaluated in the Computer Engineering Department of Adnan Menderes University Faculty of Engineering.

Body measurement values of WH, BH, RH, BL, BRH, AH, SW, and RW obtained by MM were accepted as the Y property and the same values taken by PM and 3D were taken as the X property and the linear regression and co-t-test statistical methods were evaluated using SPSS 21.1 package program.

Results

In the study, MM values were compared with the other two measurement methods (PM and 3D) statistically and in terms of their practical use. When the practicality of application of all three measurement methods on animals was compared, MM was considered to be the most difficult method because it required two people to hold the animal stable and two people to take the measurements, a total of four people while measuring manually on the same animal. MM took between 15 and 20 min. Since the female camels are very mobile, some animals were given food during the measurement. In addition, another person tried to keep the animal stable. In the application of the manual measurement method, measuring in animals has generally been difficult, dangerous, and time-consuming.

In the PM, while a photograph was taken by one person, a second person held the scale paper near the camel and the shots were taken from different angles. Another person kept the camel still during the shooting. A total of three people took part in the photo shooting and a total of three photographs were taken from the side, front, and back of each camel. The time taken for this process is approximately 3–5 min.

The comparison of various body measurements of the female camels determined by all three methods according to the least-squares averages is shown in Table 1.

|          | Groups                          | BMs  | N | MM      | 3D      | PM      | P     |
|----------|---------------------------------|------|---|---------|---------|---------|-------|
|          |                                 | WH   | 12| 171.42 ± 1.34a | 170.46 ± 1.37ab | 165.54 ± 2.22b | *     |
|          |                                 | BH   | 12| 190.40 ± 1.80a | 187.18 ± 1.61ab | 183.17 ± 2.91b | *     |
|          |                                 | RH   | 12| 164.21 ± 0.74a | 163.75 ± 1.22a | 156.75 ± 3.36a | *     |
|          |                                 | BRH  | 12| 91.17 ± 0.95a  | 88.13 ± 1.17b  | 87.26 ± 1.97b  | *     |
|          |                                 | AH   | 12| 91.00 ± 1.25a  | 86.67 ± 1.83b  | 85.42 ± 2.41b  | *     |
|          |                                 | BL   | 12| 148.75 ± 2.66a | 148.96 ± 3.35a | 137.92 ± 3.14a | *     |
|          |                                 | SW   | 12| 40.33 ± 1.52a  | 40.25 ± 1.39a  | 34.38 ± 0.83b  | *     |
|          |                                 | RW   | 12| 32.33 ± 0.75a  | 33.00 ± 0.81a  | 31.71 ± 0.85a  | NS    |

* Differences between means with different letters on the same line are statistically significant
* P < 0.05; NS, not significant

The values measured by 3D and PM methods for BRH and AH were close to each other and the difference was insignificant (p < 0.05). For these measurements, the value obtained by the PM was found to be smaller. The difference between the measurement values determined by MM and PM (p < 0.05) was found to be significant. Measurement values of RH, BL, SW, and RW were very close to each other in MM and 3D methods, and the differences were insignificant (p < 0.05), but the difference between the measurement values determined by MM and PM (p < 0.05) was found significant (Table 1).

The values measured by 3D and PM methods for BRH and AH were close to each other and the difference was found to be insignificant (p < 0.05), but the difference between MM measurement values of the same regions and the values obtained by other methods was statistically significant (p < 0.05). The reason for this is that the person who will do the measuring with MM has to go under the camel to measure AH and BRH values. It is thought that a very healthy measurement cannot be taken under these conditions because the person is afraid of going under the camel and this behavior is dangerous (Table 1).

RW was determined as 32.33 cm by MM, 33.00 cm by 3D, and 31.71 cm by PM. When the measurement values determined by MM, 3D, and PM were compared statistically, the difference between the means (p < 0.05) was found to be insignificant (Table 1).

The comparison of the male camels according to the least squares means of various body measurements determined by three methods is shown in Table 2. MM and 3D values obtained for WH, BH, RH, BRH, AH, SW, and BL in the measurements made with MM, 3D, and PM methods were considered very close to each other and the differences between them were found to be insignificant (p < 0.05). However, for these values, the differences between the values obtained by the MM and 3D methods and the values
measured by the PM method were found to be significant ($p < 0.05$). For the rump width (RW), the measurement values taken by the MM, 3D, and PM methods were found to be close to each other and the differences between them were insignificant (Table 2).

Very high and significant positive correlations were found between the values obtained by MM and 3D methods in males and females. Correlation values between MM and 3D measurements of female camels are given in Table 3. There was a positive relationship between 3D-WH and MM-WH, 3D-BH, MM-BH, 3D-RH, and MM-RH ($p < 0.01$). A high positive correlation was found between MM-WH and MM-RH ($p < 0.01$). There was a positive correlation between 3D-BH and MM-BH ($p < 0.05$). There was a high positive correlation between MM-BH and 3D-BL ($p < 0.01$) and a high positive correlation between MM-BH and MM-BL ($p < 0.05$). A positive ($p < 0.05$) relationship was found between 3D-RH and MM-RH and MM-RH and 3D-BRH. The relationship between 3D-RH and 3D-BRH ($p < 0.01$) was found to be positive. A positive ($p < 0.05$) relationship was found between MM-BRH and 3D-AH and MM-AH. A positive correlation ($p < 0.01$) was found between 3D-BRH and 3D-AH and 3D-BL and MM-BL (Table 3).

Correlation values of female camels between MM and 3D belonging to BMs (BL, SW, RW) were given in Table 4. A high positive correlation ($p < 0.01$) was found between 3D-BL and MM-BL and between 3D-BL and MM-SW. The relationship between 3D-BL and 3D-SW, 3D-BL with 3D-RW and 3D-BL, and MM-RW ($p < 0.05$) was found to be positive and significant. A high positive correlation ($p < 0.01$) was found between MM-BL and 3D-SW, MM-BL with MM-SW, MM-BL and 3D-RW, and MM-BL and MM-RW (Table 4). A high positive correlation ($p < 0.01$) was found between 3D-SW and MM-SW; between 3D-SW and 3D-RW; between 3D-SW and MM-RW; between MM-SW and 3D-RW; between MM-SW and MM-RW; and between 3D-RW and MM-RW (Table 4).

The correlation values between MM and 3D measurements of male camels are given in Table 5. A positive correlation ($p < 0.01$) was found between 3D-WH and MM-WH and 3D-BH and MM-BH. A positive correlation ($p < 0.01$) was found between 3D-RH and MM-RH and 3D-AH. The relationship between 3D-RH and 3D-BRH and 3D-RH and MM-AH ($p < 0.05$) was found to be positive. A positive correlation ($p < 0.05$) was found between MM-BRH and 3D-AH and MM-AH. The relationship between MM-BRH and MM-BH and MM-AH ($p < 0.05$) was found to be positive. A high positive correlation between MM-BBH and 3D-BBH ($p < 0.01$) and a high positive correlation between MM-BBH and MM-BHH ($p < 0.05$) relationship was found between 3D-RHH and MM-RHH and MM-RHH and 3D-BRH. The relationship between 3D-RHH and 3D-BRH ($p < 0.01$) was found to be positive. A positive ($p < 0.05$) relationship was found between MM-BRH and 3D-AH and MM-AH. A positive correlation ($p < 0.01$) was found between 3D-BRH and 3D-AH and 3D-BL and MM-BL (Table 3).

**Table 2** Comparison of male camels by means of least squares of body measurements

| Groups | BM | N  | MM | 3D | PM | P  |
|-------|----|----|----|----|----|----|
| WH    | 14 | 183.21 ± 1.46a | 183.68 ± 1.41a | 168.43 ± 2.71b | *  |
| BH    | 14 | 205.39 ± 2.67a | 205.64 ± 2.62a | 191.93 ± 3.74b | *  |
| RH    | 14 | 165.36 ± 1.95a | 164.36 ± 1.78a | 152.36 ± 3.59b | *  |
| BRH   | 14 | 92.46 ± 1.04a  | 92.57 ± 0.97a  | 86.51 ± 2.11b  | *  |
| AH    | 14 | 89.00 ± 1.36a  | 88.82 ± 1.25a  | 81.36 ± 2.12b  | *  |
| BL    | 14 | 168.39 ± 1.33a | 168.43 ± 1.23a | 148.46 ± 3.79b | *  |
| SW    | 14 | 55.64 ± 1.59a  | 57.11 ± 1.47a  | 45.79 ± 1.56b  | *  |
| RW    | 14 | 39.10 ± 1.37a  | 39.71 ± 1.18a  | 36.50 ± 0.69a  | NS |

a,b Differences between means with different letters on the same line are statistically significant

$^*$P < 0.05; NS, not significant

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**Table 3** Correlation values of female camels between MM and 3D belonging to BMs (WH, BH, RH, BRH, AH, BL)

| BMs  | 3D-WH | MM-WH | 3D-BH | MM-BH | 3D-RH | MM-RH | 3D-BRH | MM-BRH | 3D-AH | MM-AH | 3D-BL | MM-BL |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 3D-WH| 1     | 0.690*| 0.790**| 0.633*| 0.738**| 0.513*| 0.511*| 0.215*| 0.176*| 0.084*| 0.267| 0.156|
| MM-WH| 1     | 0.339 | 0.717**| 0.567 | .582* | 0.555 | 0.497 | 0.264 | 0.224 | 0.302 | 0.318|
| 3D-BH| 1     | 0.687*| 0.526 | 0.361 | 0.07  | −0.199| −0.143| −0.245| 0.548 | 0.455|
| MM-BH| 1     | 0.386 | 0.528 | 0.04  | 0.131 | −0.225| −0.15 | 0.765**| 0.683*|
| 3D-RH| 1     | 0.643*| 0.775**| 0.468 | 0.499 | 0.568 | −0.028| −0.034|
| MM-RH| 1     | 0.593*| 0.128 | 0.516 | 0.412 | 0.222 | 0.137|
| 3D-BRH| 1     | 0.443 | .790** | 0.569 | −0.263| −0.212|
| MM-BRH| 1     | 0.634*| 0.443 | −0.193| −0.182|
| 3D-AH| 1     | 0.606*| −0.482| −0.388|
| MM-AH| 1     | −0.463| −0.453|
| 3D-BL| 1     | 0.943**|

$^*$P < 0.05. **P < 0.01
correlation \((p < 0.01)\) was found between 3D-BRH and MM-BRH, 3D-BRH and 3D-AH, 3D-BRH and MM-AH, and MM-BRH and 3D-AH. A high positive \((p < 0.01)\) correlation was found between MM-BRH and MM-AH. A positive correlation \((p < 0.01)\) was found between 3D-AH and MM-AH, 3D-BL and MM-BL. As seen in Table 5, the relationship between 3D and BMs with MM was generally found to be significant.

The correlation values between MM and 3D of BL, SW, and RW measurements of male camels are included in Table 6. A high positive correlation \((p < 0.01)\) was found between 3D-BL and MM-BL, 3D-SW and MM-SW, and 3D-RW and MM-RW.

### Table 4: Correlation values of female camels between MM and 3D belonging to BMs (BL, SW, RW)

| BMs     | 3D-BL     | MM-BL     | 3D-SW     | MM-SW     | 3D-RW     | MM-RW     |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| 3D-BL   | 1         | 0.943**   | 0.668*    | 0.743**   | 0.627*    | 0.578*    |
| MM-BL   | 1         | 0.767**   | 0.777**   | 0.763**   | 0.750**   |
| 3D-SW   | 1         | 0.883**   | 0.801**   | 0.852**   |
| MM-SW   | 1         | 0.665*    | 0.734**   |
| 3D-RW   | 1         |           |           |           |
| MM-RW   |           |           |           |           |

\(*p < 0.05, **p < 0.01*

### Table 5: Correlation values of male camels between MM and 3D belonging to BMs (WH, BH, RH, BRH, AH, BL)

| BMs     | 3D-WH     | MM-WH     | 3D-BH     | MM-BH     | 3D-RH     | MM-RH     | 3D-BRH    | MM-BRH    | 3D-AH     | MM-AH     | 3D-BL     | MM-BL     |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 3D-WH   | 1         | 0.953**   | 0.177     | 0.163     | 0.36      | 0.416     | 0.19      | 0.227     | 0.484     | 0.451     | 0.477     | 0.154     |
| MM-WH   | 1         | 0.32      | 0.322     | 0.396     | 0.538*    | 0.218     | 0.258     | 0.491     | 0.454     | 0.47       | 0.306     |
| 3D-BH   | 1         | 0.995**   | −0.091    | 0.163     | 0.038     | 0.104     | −0.044    | −0.132    | 0.239     | 0.3        |
| MM-BH   | 1         | −0.077    | 0.198     | 0.062     | 0.121     | −0.023    | −0.109    | 0.238     | 0.335     |
| 3D-RH   | 1         | 0.871**   | 0.619*    | 0.494     | 0.691**   | 0.578*    | −0.08      | −0.111    |
| MM-RH   | 1         | 0.705**   | 0.641*    | 0.729**   | 0.625*    | −0.006    | 0.037     |
| 3D-BRH  | 1         | 0.948**   | 0.795**   | 0.748**   | 0.701*    | −0.031    | −0.106    |
| MM-BRH  | 1         | 0.761**   | 0.710*    | 0.094     | 0.16       |
| 3D-AH   | 1         | 0.977**   | 0.253     | 0.105     |
| MM-AH   | 1         | 0.132     | 0.195     |
| 3D-BL   | 1         |           |           |           |
| MM-BL   |           |           |           |           |

\(*p < 0.05, **p < 0.01*

### Table 6: Correlation values of male camels between MM and 3D belonging to BMs (BL, SW, RW)

| BMs     | 3D-BL     | MM-BL     | 3D-SW     | MM-SW     | 3D-RW     | MM-RW     |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| 3D-BL   | 1         | 0.780**   | −0.27     | −0.322    | 0.139     | −0.14     |
| MM-BL   | 1         | 0.14      | 0.121     | −0.098    | −0.344    |
| 3D-SW   | 1         | 0.984**   | 0.144     | 0.247     |
| MM-SW   | 1         | 0.082     | 0.225     |
| 3D-RW   | 1         |           |           |           |
| MM-RW   |           |           |           |           |

\(*p < 0.05, **p < 0.01*

Withers height

In Fig. 1, 3D-WH and MM-WH (green line) in female camels were found to be positively linear as shown in the graph. There was no linear between 3D-WH and PM-WH (blue line). Likewise, PM-WH and MM-WH (red line) were also not linear. For female camels, the \(R^2\) between MM-WH and 3D-WH was found as 0.48, the \(R^2\) between MM-WH and PM-WH as 0.18, and the \(R^2\) between 3D-WH and PM-WH as 0.07.

In Fig. 2, in male camels, 3D-WH and MM-WH (green line) were found to be positively linear as shown in the graph. There was no linear between 3D-WH and PM-WH.
Back height

In Fig. 3, 3D-BH and MM-BH (green line) in female camels were found to be linear as shown. However, 3D-BH and PM-BH (blue line) and PM-BH and MM-BH (red line) BMs were not linear. In female camels, the $R^2$ between MM-BH and 3D-BH was found as 0.30, the $R^2$ between MM-BH and PM-BH as 0.09, and the $R^2$ between 3D-BH and PM-BH as $-2.49$.

In Fig. 4, 3D-BH and MM-BH (green line) were found to be linear in male camels as shown. However, 3D-BH and PM-BH (blue line) and PM-BH and MM-BH (red line) BMs were not linear. In male camels, $R^2$ between MM-BH and 3D-BH was found as 0.99, $R^2$ between MM-BH and PM-BH as 0.24, and $R^2$ between 3D-BH and PM-BH as 0.21.

Rump height

In Fig. 5, in female camels, 3D-RH and MM-RH (green line) were found to be linear as shown. However, 3D-RH and PM-RH (blue line) and PM-RH and MM-RH (red line) were not linear. In female camels, $R^2$ between MM-RH and 3D-RH was found as 0.41, $R^2$ between MM-RH and PM-RH as 0.07, and $R^2$ between 3D-RH and PM-RH as 0.34.

In Fig. 6, in male camels, 3D-RH and MM-RH (green line) were found to be linear as shown. However, 3D-RH and PM-RH (blue line) and PM-RH and MM-RH (red line) BMs were not found to be linear. In male camels, the $R^2$
value between MM-RH and 3D-RH was found as 0.76, the $R^2$ value between MM-RH and PM-RH as 0.04, and the $R^2$ value between 3D-RH and PM-RH as 0.001.

Brisket height

In Fig. 7, in female camels, 3D-BRH and PM-BRH (blue line) and PM-BRH and MM-BRH (red line) were found to be linear as shown. However, 3D-BRH and MM-BRH (green line) BMs were not linear. In female camels, the $R^2$ between MM-BRH and 3D-BRH was found as 0.20, the $R^2$ between MM-BRH and PM-BRH as 0.36, and the $R^2$ between 3D-BRH and PM-BRH as 0.32.

In Fig. 8, in male camels, 3D-BRH and MM-BRH (green line) were found to be linear as shown. However, 3D-BRH and PM-BRH (blue line) and PM-BRH and MM-BRH (red line) BMs were not linear. In male camels, the $R^2$ between MM-BRH and 3D-BRH was found as 0.90, the $R^2$ between MM-BRH and PM-BRH as 0.11, and the $R^2$ between 3D-BRH and PM-BRH as 0.19.

Abdominal height

In Fig. 9, in female camels, 3D-AH with PM-AH, MM-AH with PM-AH, and 3D-AH with MM-AH were found to be linear as shown. In female camels, the $R^2$ between MM-AH and 3D-AH was found as 0.37, the $R^2$ between MM-AH and PM-AH as 0.60, and the $R^2$ between 3D-AH and PM-AH as 0.48.

In Fig. 10, in male camels, 3D-AH and MM-AH (green line) were found to be linear as seen. However, 3D-AH and PM-AH (blue line) and PM-AH and MM-AH (red line) BMs were not
linear. In male camels, the $R^2$ between MM-AH and 3D-AH was found as 0.96, the $R^2$ between MM-AH and PM-AH as 0.12, and the $R^2$ between 3D-AH and PM-AH as 0.07.

**Body length**

In Fig. 11, in female camels, 3D-BL and MM-BL (green line) were found to be linear as shown. However, 3D-BL/
PM-BL (blue line) and PM-BL/MM-BL (red line) were not linear. In the female camels, the $R^2$ between MM-BL and 3D-BL was found as 0.89, the $R^2$ between MM-BL and PM-BL as 0.15, and the $R^2$ between 3D-BL and PM-BL as 0.05.

In Fig. 12, in male camels, 3D-BL and MM-BL (green line) were found to be linear as seen. However, 3D-BL and PM-BL (blue line) and PM-BL and MM-BL (red line) were not linear. In male camels, the $R^2$ between MM-BL and 3D-BL was found as 0.61, the $R^2$ between MM-BL and PM-BL as 0.10, and the $R^2$ between 3D-BL and PM-BL as 0.23.

**Shoulder width**

In Fig. 13, in female camels, 3D-SW and MM-SW (green line) were found to be linear as shown. However, 3D-SW and PM-SW (blue line) and PM-SW and MM-SW (red line) were not linear. In female camels, the $R^2$ between MM-SW and 3D-SW was found as 0.78, the $R^2$ between MM-SW and PM-SW as 0.001, and the $R^2$ between 3D-SW and PM-SW as 0.002.

In Fig. 14, in male camels, 3D-SW and MM-SW (green line) were found to be linear as shown. However, 3D-SW and PM-SW (blue line) and PM-SW and MM-SW (red line) BMs were not found to be linear. In the male camels, the $R^2$ between MM-SW and 3D-SW was found as 0.97, the $R^2$ between MM-SW and PM-SW as 0.02, and $R^2$ between 3D-SW and PM-SW as 0.02.
In Fig. 15, in female camels, 3D-RW and MM-RW (green line), 3D-RW and PM-RW (blue line) and PM-RW and MM-RW (red line) were found to be linear as shown. In female camels, the $R^2$ between MM-RW and 3D-RW was found as 0.67, the $R^2$ between MM-RW and PM-RW as 0.41, and the $R^2$ between 3D-RW and PM-RW as 0.31.

In Fig. 16, in male camels, 3D-RW and MM-RW (green line) were found to be linear as seen. However, 3D-RW and PM-RW (blue line) and PM-RW and MM-RW (red line) BMs were not found to be linear. In male camels, the $R^2$ between MM-RW and 3D-RW was found as 0.83, the $R^2$ between MM-RW and PM-RW as 0.07, and the $R^2$ between 3D-RW and PM-RW as 0.03.

**Discussion**

Many studies have been conducted to find practical and easy methods for taking body measurements of farm animals. Tasdemir et al. (2011) conducted studies on Holstein cows using MM and PM, and Wu et al. (2004) studied pigs using multiple cameras. Numerous studies have been conducted on image processing, mostly with photography, video processing, thermography, and thermal image analysis methods (Tözsér et al. 2000; Wu et al. 2004; Stajnko et al. 2008; Genç, 2018). The results of these studies, which were carried out for 3D imaging using numerous cameras and equipment, were found to be successful; however, there was not enough improvement in the practical use of these measuring methods. With the development of digital technology and the use of industry 4, 0 in the field of agriculture, it is seen that 3D...
imaging and image processing methods in livestock farming have been used in studies to determine the morphological and physiological characteristics of animals in the last 2 years. In a study, it was reported that a full-body scan was performed by placing five three-dimensional (3D) imaging devices on a fixed platform to capture images from all angles to monitor the morphology and growth of 64 heads of Holstein cows (Le Cozler et al. 2019). In this study, a full-body scan was performed by rotating 360° around the animal with a single three-dimensional imaging device. There are many studies on determining the morphological characteristics of camels. However, there is no study conducted with the 3D method (Belkhir et al. 2013; Yosef et al. 2014; Legesse et al. 2018; Vyas et al. 2018; Boujenane et al. 2019; Diop et al. 2020). With this method, which we used on the basis of the 3D method, and in extensive conditions without the need for a platform or a large number of cameras, body measurements of animals can be taken easily and without causing stress in the animals with a crowded measurement team.

Instead of using many cameras and different imaging systems and platforms for three-dimensional images, it has been seen in our study that all measurements can be determined using a single three-dimensional imaging device and a computer program.

**Conclusion**

As a result of this study, it has been revealed that measuring some morphological characteristics of large animals such as camels from a distance using an easy and practical three-dimensional modeling method is reliable. It also takes very short time and not many helpers are needed to control the animals.

The 3D method is a measurement method that can enable to take measurements in large farm animals without touching them, without causing stress to them, and without fear for the researcher or breeder who takes the measurements. In addition, considering the difficulties in monitoring the general situation of cattle breeding (camel, cattle, buffalo, horse) enterprises, the ease of the use of the 3D measurement method will also provide time and economic gain by supporting herd management.

A single three-dimensional camera can be used to determine the relationship or abnormalities between the body parts of animals and to detect damages such as lesions and injuries, etc. in the body, as in this study. The results of this study demonstrated that more studies should be conducted on taking measurements with the 3D method, and this method should be tested and developed in different breeds as well. In addition, it could also be possible to estimate the animals’ weights with this method; however, we did not have the opportunity to weigh the animals before we started the study. It is thought that this method will become widely used in taking morphological measurements of animals in animal breeding and studies for scientific purposes in the near future.

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The authors declare that the manuscript complies with the Ethical Rules applicable for Tropical Animal Health and Production Journal.

**Declarations**

**Conflict of interest** The authors declare no competing interests.

**References**

Belkhir, A. O., Chehma, A., & Faye, B. (2013). Phenotypic variability of two principal Algerian camel’s populations (Targui and Sahraoui). Emirates Journal of Food and Agriculture, 231-237.

Biykoğlu, K. 1973. Genel Zootekni. Atatürk Üniversitesi Yayınları.

Biykoğlu, K. 1973. Genel Zootekni. Atatürk Üniversitesi Yayınları.

Boujenane, I., El Khattabyy, N., Laghouaouta, B., Badawi, H., & Pirro, M. (2019). Morphological diversity of female camel (Camelus dromedarius) populations in Morocco. Tropical animal health and production, 51(6), 1367-1373.

Diop, A. K. M., Ahmed, C., Mohamed, S., Biya, M. B., Haki, M. L., Konuspayeve, G., & Faye, B. (2020). Comparaison des phénotypes camels de Mauritanie aux écotypes d’Afrique et d’Asie.

Genç, S. 2018. Comparison of Classical and Photograph Method of Body Measurements in Awassi Sheep. Black Sea Journal of Engineering and Science, 1(4), 130-133.

Koç, A., Bülbül, A., Birincioglu, B., Altun, T. 2018. Çift Hörçülü (Bactrian) Ve Tek Hörçülü (Dromedar) F1 Melezi (Tülü) Budukların Doğum Ağırlığı Ve Vücut Ölçüleri Üzerine Bir Araştırma. In second International Selçuk-Ephesus Symposium On Culture Of Camel-Dealing And Camel Wrestling Volume II National And Applied Science Health And Medical Science, 1:31-41.

Le Cozler, Y., Allain, C., Xavier, C., Depuille, L., Caillot, A., Delouard, J. M., Faverdin, P. 2019. Volume and surface area of Holstein dairy cows calculated from complete 3D shapes acquired using a high-precision scanning system: Interest for body weight estimation. Computers and Electronics in Agriculture, 165, 104977.

Legesse, Y. W., Dunn, C. D., Mauldin, M. R., Ordonez-Garza, N., Rowden, G. R., Gebre, Y. M., ... & Bradley, R. D. (2018). Morphometric and genetic variation in 8 breeds of Ethiopian camels (Camelus dromedarius). Journal of animal science, 96(12), 4925-4934.

Manav, S., Koç, A. 2018. Aydın İlinde Güreş Devesi Yetiştiriciliği, Bakım-Beslemeesi Ve Yetiştiricilerin Sorunları Üzerine Bir Değerlendirme. II. Uluslararası Devecilik Kültürü ve Deve Güreşleri Sempozyumu Kasımpaşa İstanbul II. Cilt Fend Ve Sağlık Bilimleri, s: 12-21.

Meghelli, I., Kaouadi, Z., Yilmaz, O., Cemal, I., Karaca, O., Gaour, S. B. S. 2020. Morphometric characterization and estimating body weight of two Algerian camel breeds using morphometric measurements. Tropical animal health and production.
Ozdogan, B., Gacar, A., Aktas, H. 2017. Digital agriculture practices in the context of agriculture 4.0. J. Econ. Financ. Account, 4, 186-193.

Ozkaya, S. 2012. Accuracy of Body Measurements Using Digital Image Analysis in female Holstein calves. Animal Production Science, 52(10), 917-920.

Ozsoylu, A. F. 2017. Industry 4.0. Journal of Çukurova University Faculty of Economics and Administrative Sciences, 21(1), 41-64.

Stajnko, D., Brus, M., Hočevar, M. 2008. Estimation of bull live weight through thermographically measured body dimensions. Computers and Electronics in Agriculture, 61(2), 233-240.

Şekerden, Ö., Özkütük, K. 1990. Büyükbaş hayvan yetiştirme. Çukurova Üniversitesi Ziraat Fakültesi Ders Kitabı, 122.

Şekerden, Ö., Tapkı, I. 2003. Hatay İli Anadolu mandalarında köy şartlarında büyüme özellikleri. Atatürk Üniv. Zir. Fak. Derg, 34(1), 51-55.

Tasdemir, S., Urkmez, A. and Inal, S. 2011. Determination of body measurements on the Holstein cows using digital image analysis and estimation of live weight with regression analysis. Computers and Electronics in Agriculture, 76(2), 189-197.

Tien, N. Q. and Tripathi, V. N. 1990. Genetic Parameters of Body Weight at Different Ages and First Lactation Traits in Murrah Buffalo Heifers. Indian Veterinary Journal, 67(9), 821-825.

Tözsér, J., Sutta, J., Bedő, S. 2000. The evaluation of video pictures for measurements of cattle. Állatteny Takarm. 49:385–392.

Velea, C., Bud, I., Muresan, G., David, V., Vomir, M., Cristea, C., Elisei, L. 1991. The main milk traits of Romanian buffaloes breed. In Third World Buffalo Congress, Varna, Bulgaria, 494-499.

Vyas, P., Mehta, S. C., & and Pallavi Joshi, U. P. (2018). Genetic and phenotypic trends of different body parameters in Indian dromedary breeds.

Wu, J., Tillett, R., McFarlane, N., Ju, X., Siebert, J. P., Schofield, P. 2004. Extracting the three-dimensional shape of live pigs using stereo photogrammetry. Computers and Electronics in Agriculture, 44(3), 203-222.

Yılmaz, O., Ertürk, Y. E. and Ertuğrul, M. 2013. Some Phenotypical Characteristics of Camels Raised in Provinces of Balikesir and Canakkale of Turkey. Çanakkale Onsekiz Mart University Journal of the Faculty of Agriculture,1:51-56.

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