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Evaluation of somatotype in the reticulated giraffe (*Giraffa camelopardalis reticulata*) using three-dimensional laser measurement

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ABSTRACT. The giraffe (*Giraffa camelopardalis*) is a difficult animal to keep in captivity as it has high mortality due to nutrition-related disorders, perhaps because the giraffe's condition is difficult to evaluate. Image analysis techniques have recently become popular and may be useful for evaluating the giraffe's somatotype. The present study aimed to evaluate the giraffe somatotype using a three-dimensional laser measurement device, and to examine the usefulness of this method. First, ten zoo staff members visually evaluated the somatotypes of three giraffes housed at Kanazawa Zoological Gardens, Japan. Next, three-dimensional point cloud datasets were obtained from these giraffes using the device. The point cloud datasets indicated that the cross-sectional area and width of the largest giraffe's body were large in the abdominal region in the transverse sections. However, by visual examination, the ten zoo staff members deemed a different giraffe to be the largest. These results indicated that the three-dimensional laser measurement device could be used to evaluate giraffe somatotype in detail, and that this method may be an alternative to visual evaluation.

KEY WORDS: area, body score, body width, *Giraffa camelopardalis*, nutritional status

The giraffe (*Giraffa camelopardalis*) is the tallest terrestrial animal and is kept in many zoos worldwide. Although many people are passionate about keeping captive giraffes in healthy conditions, the health management of the giraffe is difficult. Several studies have described giraffe mortality associated with poor nutrition [5, 10, 12, 16]. Although the frequency has decreased recently because of improved feeding practices [2], several death cases that might be associated with poor nutrition have still been reported in Japan, also known as the acute mortality syndrome. These giraffe deaths are due to a negative energy balance or insufficient nutrition, poor dental health, hypothermia and/or stress [2, 5, 7, 12, 16]. Commonly, negative energy balance and insufficient nutrition of the giraffe feed are mainly because of the high starch and low fibre diet specific in a zoo [6]. This unbalanced diet is unsuitable for the giraffe, a browser, and induces lumen acidosis; as a result, the giraffes lose weight and become emaciated, and finally die. To prevent this type of death, it is important to evaluate the nutritional status of the giraffe. However, this is difficult because body weight, a basic healthcare factor, cannot be measured in many zoos as they lack scales for megafauna. In addition, somatotype evaluations in productive animals, such as calculation of the body conditioning score (BCS), is often inaccurate in giraffes because they have thick skin and the anatomical feature is difficult to identify [17]. Although the Nutritional Advisory Group of the Association of Zoos and Aquariums suggested a model for determining giraffe body score, they noted that it was subjective [15]. Therefore, it is important that researchers introduce an alternative method for the giraffe somatotype.

Since 1990s, the BCS has been a mainstream method of animal somatotype evaluation, especially in productive animals [4]. However, BCS evaluation involves a human bias, even though various anatomical checkpoints have been recommended to eliminate it. In this regard, it is relevant that image analysis techniques have improved dramatically in recent years. Recently, three-dimensional laser measurement has been applied in various fields such as industrial installation, city landscape, digital elevation, and archaeology [13, 18]. Moreover, in medical science, this analysis technique has been applied, especially in orthopaedics, ophthalmology, dermatology, forensic analysis, and dentistry [8]. In productive cattle, several studies have evaluated the BCS measurement using image analysis techniques such as three-dimensional analysis [1, 3, 9, 11, 14]. This technique may be useful for evaluating the giraffe somatotype. The present study aimed to evaluate the efficacy of the three-dimensional laser measurement

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Fig. 1. A handheld three-dimensional laser measurement device connected to the laptop by USB cable.

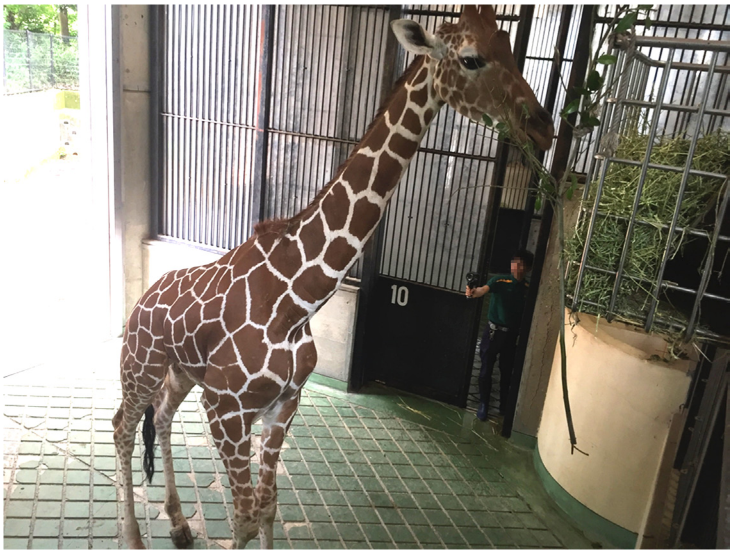

Fig. 2. Operational scene (reproduction). Photographers stood in the next room and obtained the data from the opening between the doors. The data was simultaneously obtained from the left and right sides using two measurement devices.

for the giraffe somatotype, which was compared with that of the BCS evaluation.

MATERIALS AND METHODS

Animals

The present study involved three reticulated giraffes (*Giraffa camelopardalis reticulata*) housed at Kanazawa Zoological Gardens (Yokohama, Japan). Two of the giraffes were female: aged 13 (No. 1) and twelve years (No. 2); the other was a male: aged two years (No. 3), in 2017. Both the females had given birth two years prior to the study (the dam of No. 3 was different) and had not been pregnant since.

Evaluation of body score and obesity ranking

The body scores of the three giraffes were evaluated according to the guidelines of the North America Giraffe Body Score Project (2005) by ten zoo staff members [15].

Instruments

Three-dimensional images of the giraffes were obtained using a handheld three-dimensional laser measurement device: the F6 SMART (Mantis Vision Ltd., Petach Tikva, Israel; Fig. 1). The giraffes' images were simultaneously obtained from the left and right sides, using two measurement devices that were placed approximately 2 m away (Fig. 2). It took one to two min to obtain a three-dimensional image. This point cloud dataset was analysed using Galaxy-Eye software (Fuji Technical Research Inc., Yokohama, Japan), which converted it from a three-dimensional laser measuring dataset to a computer-aided model.

Measurement

Images of the dorsal and transverse sections of the body were obtained. In the dorsal sections, the body length was measured from the protrusion of the proximal end of the humerus. In the transverse sections, the body circumference, cross-sectional area, width, and height were measured every five cm between the axillary and inguinal regions. In areas where the point cloud datasets were absent, the data was estimated on the basis of the other individuals' datasets. To evaluate the somatotype of the giraffe, the measured values from the transverse sections were divided by the body length. The degree of change, that indicated how the abdominal region changed from the body centre to the inguinal region, was calculated as the value of the inguinal region subtracted from that of the body centre. Measurements were conducted using a length and area measuring software (Microsoft Excel; Japan Microsoft Co., Tokyo, Japan).

The body circumference of the No. 3 giraffe in standing position was directly measured in the axillary region with a measuring tape.

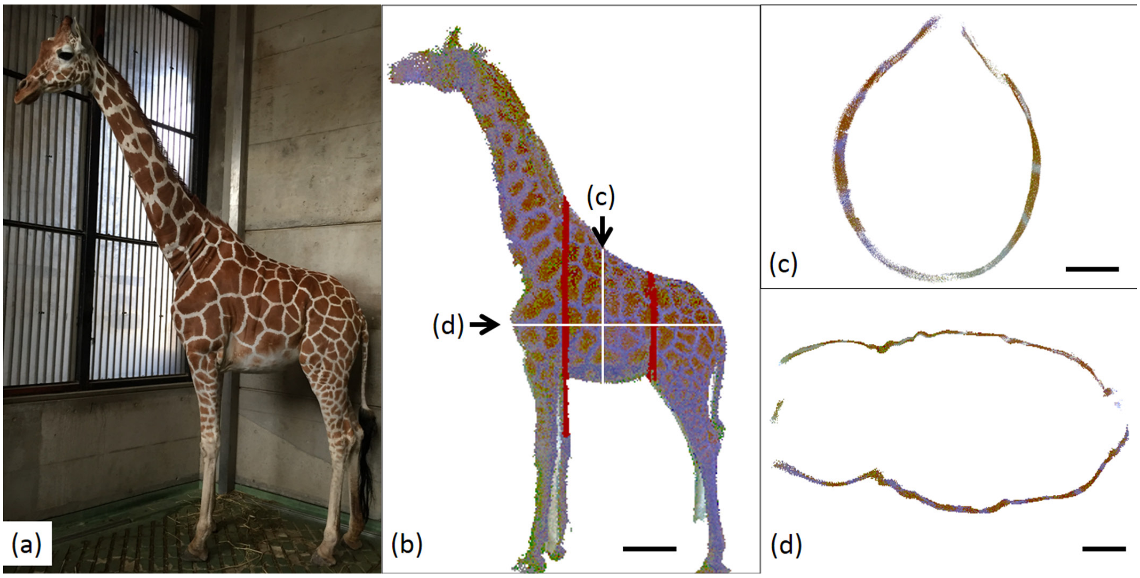

Fig. 3. Actual figure and three-dimensional point cloud datasets of reticulated giraffe No. 1. (a) Actual figure. (b) Whole body: transverse sections obtained every five centimetres from the axillary and inguinal regions (between the red lines). Scale bar: 40 cm. (c) Transverse section in the body centre (white line "c" in Fig. 3b). Scale bar: 20 cm. (d) Dorsal section of the protrusion at the proximal end of the humerus (white line "d" in Fig. 3b. Scale bar: 20 cm.

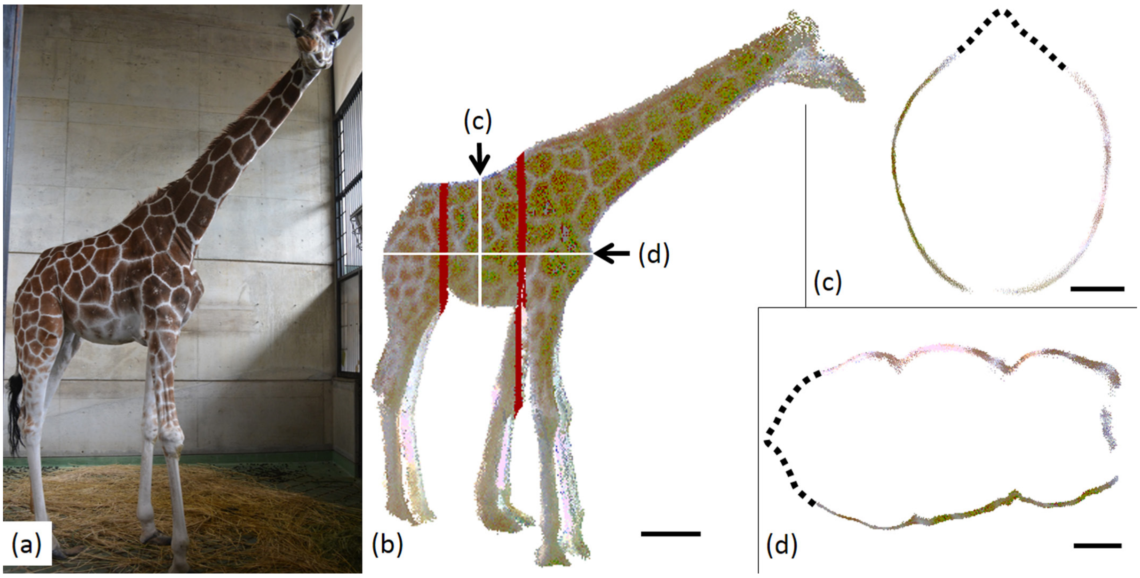

Fig. 4. Actual figure and three-dimensional point cloud datasets of reticulated giraffe No. 2. (a) Actual figure. (b) Whole body: transverse sections obtained every five centimetres from the axillary and inguinal regions (between the red lines). Scale bar: 40 cm. (c) Transverse section in the body centre (white line "c" in Fig. 4b). The dorsal point cloud datasets were absent. Therefore, the dotted line was estimated on the basis of the datasets from No. 1. Scale bar: 20 cm. (d) Dorsal section of the protrusion at the proximal end of the humerus (white line "d" in Fig. 4b). The point cloud datasets of the gluteal region were absent. Therefore, the dotted line was estimated on the basis of the datasets from No. 1. Scale bar: 20 cm.

RESULTS

The giraffes' body scores, as evaluated by the ten zoo staff members, were as follows: Nos. 1, 2, and 3 had average scores of 3.3, 2.5, and 3.0, respectively.

The three-dimensional point cloud datasets of the three giraffes were obtained (Figs. 3–5) and the transverse and dorsal sections were described. In No. 2, the datasets were absent in the dorsal and gluteal regions, and therefore the data was estimated based on

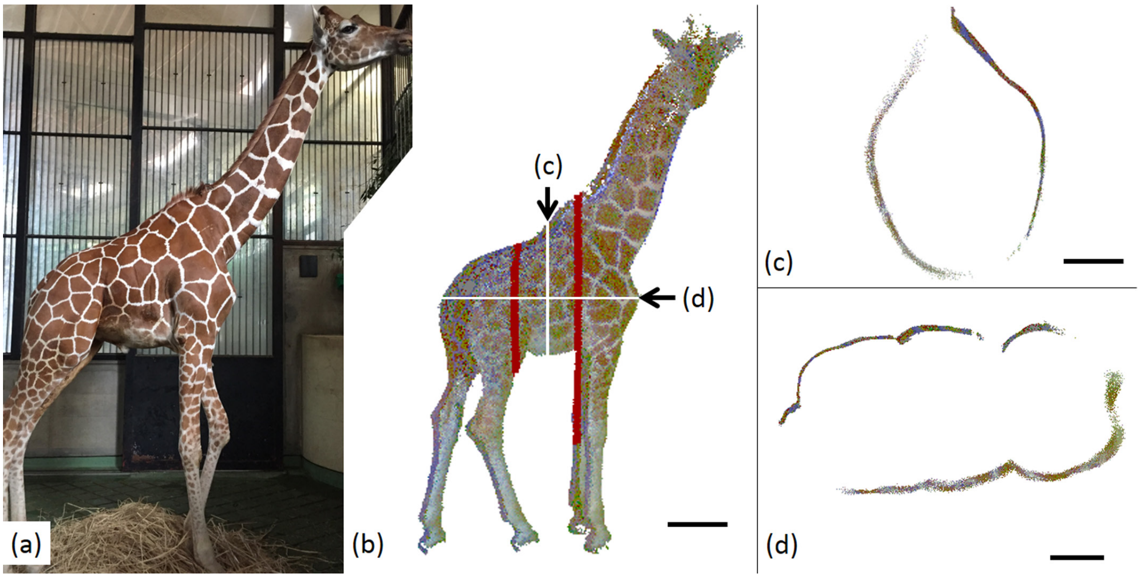

Fig. 5. Actual figure and three-dimensional point cloud datasets of reticulated giraffe No. 3. (a) Actual figure. (b) Whole body: transverse sections obtained every five centimetres from the axillary and inguinal regions (between the red lines). Scale bar: 40 cm. (c) Transverse section in the body centre (white line "c" in Fig. 5b). Scale bar: 20 cm. (d) Dorsal section of the protrusion at the proximal end of the humerus (white line "d" in Fig. 5b). Scale bar: 20 cm.

the dataset accurately obtained from No. 1. The body length and degree of change, as well as the values of body circumference, cross-sectional area, height, and width divided by the body length, are shown in Table 1. The No. 2 giraffe had the largest body circumference, cross-sectional area, and width per body length. The body cross-sectional area of the No. 1 giraffe was markedly lower around the inguinal region than that of No. 2. The body widths of Nos. 1 and 3 were almost the same. Although body height decreased from the axillary to the inguinal regions in all giraffes, body width increased.

The body circumference of No. 3 in standing position was 220 cm in the axillary region.

DISCUSSION

The present study revealed that the three-dimensional laser measurement technique was possible even in giraffes, where such calculations are normally difficult, and useful for the evaluation of the giraffe somatotype. Such an alternative evaluation method has long been required. Several previous studies have described adipose atrophy, wasting syndrome, and sudden death associated with nutritional status in giraffes [10, 12, 16]. Therefore, it is important that researchers and zoo staff evaluate giraffe body weight and/or somatotype. However, no methods have been generalised to do so because not all facilities have scales that can weigh giraffes. In addition, somatotype evaluation in giraffes has involved human subject bias. The reasons are as follows: (1) the ribs and pelvis, which are important anatomical points in BCS measurement and are normally seen when animals lose weight, cannot easily be identified in giraffes because the animals have thick skin [17]; (2) the body size of giraffes varies among individuals and a difference of few centimetres is difficult to measure. Therefore, the present methodology may become an alternative method for somatotype evaluation in other megafauna, and not just for the giraffe.

In the present study, the visual evaluation by the staff failed to correspond with the three-dimensional measurement. Specifically, visual evaluation showed that No. 1, with the highest body score, was ranked as obese. However, the three-dimensional measurement data per body length showed that No. 2 had the largest body cross-sectional area and width. In addition, the degree of change in the abdominal region indicated that the abdomen around the inguinal region had not reduced in No. 2. Further study is required to optimise this measurement system. Nonetheless, the present study found that No. 2 could be the most obese.

The results of the present study implied that visual evaluation can be affected by human bias, especially in megafauna such as the giraffe. Evaluation of body score in the giraffe was difficult for people who lacked sufficient experience; hence, training was necessary to compare various body score types simultaneously. In most cases, it was difficult for many of the zoo staff to obtain the required experience. Therefore, somatotype evaluation using three-dimensional datasets may constitute an alternative to visual assessment.

The accuracy of three-dimensional measurement might vary to some extent. The results summarized in Table 1 show that the measurement data were irregular in each part. This might be caused by the accumulation of the minute error during measurement by the length and area measuring software. Moreover, the direct measurement of the body circumference of No. 3 by the tape measure (220 cm) was approximately 32 cm different from the three-dimensional measurement (252.74 cm). However, the data for the region five cm behind axillary region was 237.12 cm. Therefore, these differences could be due to the small difference in the

Table 1. Body length, and the values of body circumference, cross-sectional area, height, and width divided by body length, are shown in three reticulated giraffes every 5 cm from the axillary to the inguinal regions. Degree of change was calculated as the value of inguinal region subtracted from that of the body centre

	Distance from axillary region		0	5	10	15	20	25	30	35	40	45	50	55	60	65	Degree of change
No. 1	Body length	171.00															
	Body circumference		1.77	1.80	1.81	1.69	1.68	1.73	1.62	1.65	1.63	1.55	1.53	1.49	1.42	1.44	0.18
			303.43	307.76	310.32	289.26	288.07	295.92	276.91	281.41	278.71	265.68	261.81	254.29	242.69	245.73	
	Body cross-sectional area		33.22	33.38	36.10	32.91	33.69	35.98	32.43	34.66	34.66	31.60	31.03	28.72	25.57	26.79	5.64
			5,680.95	5,708.47	6,173.31	5,627.64	5,761.84	6,152.74	5,546.19	5,926.20	5,926.40	5,403.88	5,306.69	4,910.33	4,371.66	4,581.70	
	Body width		0.37	0.40	0.42	0.40	0.42	0.46	0.45	0.48	0.48	0.48	0.48	0.48	0.46	0.46	−0.01
			62.65	67.65	71.18	68.92	71.84	78.42	76.34	82.44	82.86	81.34	82.61	81.88	77.84	78.24	
	Body height		0.73	0.73	0.74	0.68	0.65	0.66	0.60	0.60	0.58	0.54	0.53	0.50	0.46	0.46	0.14
			125.59	125.29	125.88	117.03	111.84	112.90	102.68	102.20	99.76	92.00	90.65	86.04	78.63	78.43	
No. 2	Body length	[151.43]															
	Body circumference		1.72	1.86	1.80	1.75	1.78	1.79	1.86	1.75	1.74	1.74					0.04
			[261.09]	[281.14]	[272.73]	[265.46]	[269.63]	[270.33]	[282.34]	[265.38]	[264.11]	[262.93]					
	Body cross-sectional area		30.18	35.87	34.98	34.17	36.49	37.03	40.34	36.08	34.71	34.61					1.88
			[4,569.87]	[5,431.66]	[5,296.57]	[5,174.92]	[5,525.35]	[5,607.76]	[6,109.42]	[5,463.28]	[5,255.62]	[5,240.44]					
	Body width		0.45	0.49	0.49	0.49	0.52	0.52	0.55	0.54	0.53	0.53					−0.02
			67.75	74.33	74.87	74.60	78.00	79.12	83.75	82.50	80.63	81.00					
	Body height		0.68	0.70	0.66	0.63	0.63	0.61	0.61	0.60	0.55	0.55					0.08
			[103.5]	[106.49]	[99.19]	[95.41]	[94.86]	[92.06]	[92.19]	[90.63]	[83.75]	[82.67]					
No. 3	Body length	136.80															
	Body circumference		1.85	1.73	1.64	1.77	1.70	1.67	1.57	1.52							0.26
			252.74	237.12	224.20	242.61	232.75	228.46	214.56	207.38							
	Body cross-sectional area		28.42	25.11	22.34	27.71	27.91	27.51	25.10	24.14							3.58
			3,888.26	3,435.33	3,056.45	3,791.06	3,818.37	3,763.17	3,433.83	3,302.00							
	Body width		0.42	0.40	0.40	0.42	0.46	0.47	0.46	0.45							−0.02
			58.00	54.29	54.29	57.88	62.26	64.00	63.33	61.00							
	Body height		0.77	0.71	0.69	0.69	0.66	0.63	0.57	0.54							0.15
			105.14	97.14	94.29	93.94	90.32	85.67	77.67	73.34							

Unit: cm. The values with a grey background are the actual measurements by length- and area-measuring software. The values in parentheses are estimations that were made because some of the point cloud datasets was absent. The underlined value was used to calculate the degree of change.

measurement points or the minute error of the three-dimensional measurement. Further studies may be required to obtain accurate datasets.

The present study evaluated the whole body of the giraffe. To calculate the BCS in cattle, the tail, head and/or lumbar regions are usually evaluated using image analysis and three-dimensional measurement [1, 3, 9, 11]. However, the present study was the first trial to use this technique in the giraffe, though it remains unclear which anatomical parts reflected obesity or emaciation. In addition, we concluded that the tail, head and lumbar regions of the giraffe do not clearly reflect obesity and emaciation in the giraffe, as they do in cattle. Therefore, the whole body of the giraffe was measured in the present study.

The present study did not directly evaluate the subcutaneous and/or visceral adipose, and our result may be a reflection of the differences in skeletal structure. However, No. 2 had the largest abdominal region unaffected by the skeletal structure. Therefore, in the giraffe, it may be more useful to evaluate the abdominal region, which may now become one of the check points of a giraffe's condition. Although measurement of the tail, head and lumbar regions should be examined in more detail, the specific anatomical parts that reflect a giraffe's condition should be elucidated, and future studies should focus on using a larger sample size.

The technique used in the present study may be applicable to a large number of species, because, other than several distances, the point cloud dataset was easily obtained within a short time and without anaesthesia. In addition, the instrument is handheld and can be used anywhere. Therefore, datasets could also be obtained from wild giraffes and compared with those of captive animals. Moreover, this information could help in the conservation of the wild species, because researchers can now evaluate the nutritional status in these giraffes. Further study is required to increase the number of measurements in various situations and species.

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