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Research article

Body condition scores of European zoo elephants (*Elephas maximus* and *Loxodonta africana*): Status quo and influencing factors

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Keywords: body condition scoring, zoo elephants

Article history:
Received: 05 Jan 2018
Accepted: 19 Jun 2018
Published online: 31 Jul 2018

Abstract

Obesity is a common problem in captive elephants. Therefore, physical state monitoring presents a critical aspect in preventive elephant healthcare. Some institutions lack the equipment to weigh elephants regularly, so body condition scoring (BCS) is a valuable alternative tool. As yet, the BCS of both elephant species has not been assessed comprehensively for the European captive population. Using a previously validated visual BCS protocol, we assessed 192 African (*Loxodonta africana*) and 326 Asian elephants (*Elephas maximus*) living in European zoos (97% of the living European elephant population). The majority of elephants scored in the upper categories with 56% of adults assessed in the range 7–10 out of 10. Adult Asian elephants had significantly lower BCS (males: mean 6.2 ± 1.0, median 6.0, range 4–8; females: mean 6.6 ± 1.3, median 6.0, range 3–9) than African elephants (males: mean 6.7 ± 0.7, median 6.0, range 6–8; females: mean 6.9 ± 1.2, median 6.0, range 1–9). Comparison with samples of free-ranging populations (163 Asian elephants and 121 African elephants) revealed significantly lower scores in free-ranging elephants independent of species, age and sex category. Compared to previous reports from captive populations, the European zoo elephant population is nevertheless less obese. In adult Asian elephant females, BCS was significantly correlated to their breeding status with lower scores in current breeders; however, breeding status was also correlated to group size, enclosure size, and a diet with less vegetables. Further attention to zoo elephant weight management is recommended with regular longitudinal monitoring by body condition scoring.

Introduction

Because of their body size, intelligence, importance to the public and conservation status, captive management of African (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) is challenging. Optimising nutritional intake for elephants in captivity can be problematic, and several reports have highlighted the problems of feeding regimes and found obesity to be common (Harris et al. 2008; Hatt and Clauss 2006; Morfeld et al. 2016). Weight management is therefore an important focus for good elephant husbandry, and body weight monitoring an important part of preventative medicine. However, the sheer size and expense of the required technical equipment means regular weight monitoring might not be feasible for many elephant-keeping zoos. Visual body condition scoring (BCS) is considered a useful method to reliably assess zoo animals including elephants (reviewed in Schiffmann et al. 2017), although none of these have defined an ideal score range with regards to health.

Several indices have recently been developed for elephants and applied in free-ranging as well as semi-captive and captive populations (Fernando et al. 2009; Morfeld et al. 2014; Morfeld et al. 2016; Treiber et al. 2012; Wemmer et al. 2006; Wijeyamohan et al. 2015). Scores are affected by age (Chusyd et al. 2018; Somgird et al. 2016b), sex (Godagama et al. 1998; Morfeld et al. 2016; Pinter-Wollman et al. 2009; Ramesh et al. 2011), living conditions (Morfeld et al. 2014; Wijeyamohan et al. 2015), season (Albl 1971; De Klerk 2009; Foley et al. 2001; Pinter-Wollman et al. 2009; Pokharel et al. 2017; Ramesh et al. 2011; Ranjeewa et al. 2018), husbandry parameters (Harris et al. 2008; Morfeld et al. 2016), reproductive status such as lactation (De Klerk 2009), faecal glucocorticoid metabolites (Pokharel et al. 2017), history of translocation (Pinter-Wollman et al. 2009) and duration of musth (Poole 1989; Somgird et al. 2016b). More extended information on previous research on elephant body condition scoring is compiled in Supplement 1 (Table S1 and S2).

In general, values in the middle range of an index are considered ideal with reference to the protocols in pets and farm animals (Santarossa et al. 2017). Based on these assumptions, a high percentage of zoo elephants in the UK and North America have been evaluated as overweight or obese (Harris et al. 2008; Morfeld et al. 2016). Morfeld et al. (2016) conducted an extensive review of the North American zoo elephant population (240 elephants in 65 institutions). However, apart from Harris´ (2008) welfare evaluation of the entire UK zoo elephant population (n=70), no study has applied a BCS index to a substantial sample size in European captive elephants, which consists of about 500 individuals (Schwammer and Fruehwirth 2015; van Wees and Damen 2016). The aim of the present study was to establish a population-wide overview of elephant body condition in these 500 animals and to perform a comparison to two free-ranging populations.

Material and methods

In January 2016, 189 African and 294 Asian elephants were included in the European endangered species program (EEP) studbooks for the European zoo elephant population. The studbook for the Asian species provides a list of 51 elephants that do not participate in the EEP. A corresponding list does not exist for the African elephant, although several individuals not recorded in the EEP are known to live in European zoos, resulting in a total of 534 individual elephants considered in our study.

Life history and husbandry data collection

Basic life history data of the individual elephants were taken from the current compilations in the EEP-studbooks at the end of March 2017 with subsequent data analysis until November 2017. Additionally, information concerning management system, enclosure sizes, diet composition, feeding regime, weight documentation and reproductive status were collected by interviewing staff members (veterinarians, curators and keepers) during visits on site or by questionnaire via mail or phone.

Body condition scoring

We used one standardised photograph showing the elephant in side profile as basis for the scoring, as for other recent scoring protocols (Fernando et al. 2009; Morfeld et al. 2014; Morfeld et al. 2016; Wijeyamohan et al. 2015). Pictures of European zoo elephants were taken while visiting facilities on site, and facilities

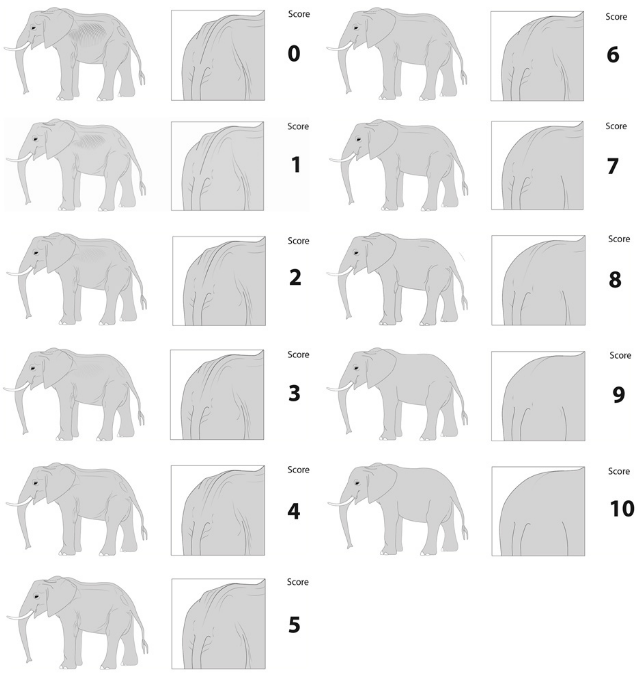

Figure 1. Example drawings used for body condition scoring of African elephants (Loxodonta africana) (drawings by Jeanne Peter)

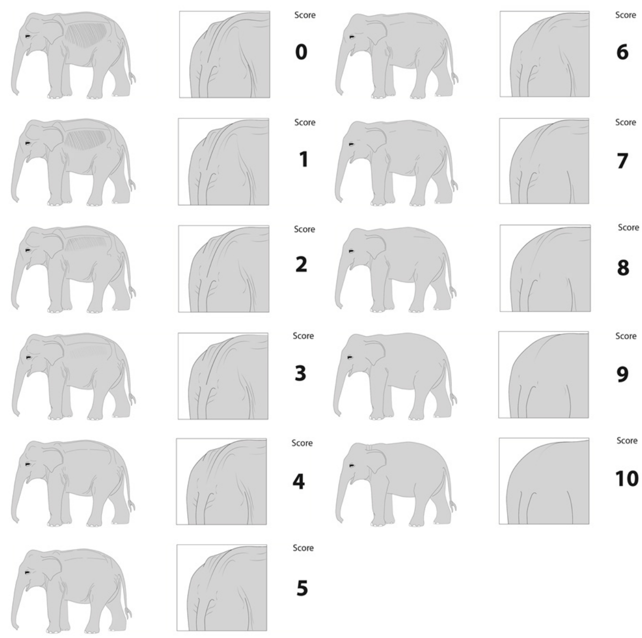

Figure 2. Example drawings used for body condition scoring of Asian elephants (Elephas maximus) (drawings by Jeanne Peter)

in which a personal visit was not feasible were contacted by mail or phone and asked to provide current photographs of their individual elephants. To be included in the study, a pictorial document had to fulfill the following criteria: i) datable to a month (where an accurate date was missing, the 1st day of the month was recorded); ii) clearly identifiable individual; iii) sufficient recognition of the relevant body regions (backbone, pelvic bone, ribs, skin fold on the base of the tail); iv) standing or moderate walking body position to allow reliable assessment; and v) adequate resolution of the photograph, based on recognition of the generic wrinkles on the skin surface of the elephant, absence of distinct patterns of shade or large amounts of hay, straw or other substrates on the back of the elephant.

To assign a consistent BCS to every photograph we combined species-specific indices in an overview following Schiffmann et al. (2017) (for African elephants from Morfeld et al. 2014; for Asian elephants from Fernando et al. 2009, Wijeyamohan et al. 2015 and Morfeld et al. 2016). Recent work has suggested scoring may reach a higher reproducibility and repeatability by using example drawings as opposed to pictures (Vieira et al. 2015). Therefore, we had exemplar drawings made for every score and each species that showed elephants in side profile and from behind (Figures 1 and 2). The focus was laid on the visibility of indicated bone structures of the lumbar region, which have been shown to correlate best with the amount of body fat in elephants (Albl 1971; Morfeld et al. 2014; Morfeld et al. 2016). In addition, the overall appearance of the elephant was taken into account and was considered more important than single characteristics (e.g. visibility of ribs or edges of the scapula), following the findings of Schiffmann et al. (2017). Elephant pictures were scored independently of age and sex by the first author, using the technical size of the picture to generate a random order to reduce observer bias. To check the method for intra-examiner agreement, a random sample (n=500) of pictures was evaluated twice and scores compared.

Collection of pictorial samples from free-ranging populations

We collected a sample of photographs from both species from the wild. For the Asian elephant, 163 photographs of the Yala National Park (Sri Lanka; 6° 16´N, 81° 20´ E) population taken randomly between 2006 and 2014 were scored. The individually pictured elephants were grouped into the following age and sex categories: calves (<5 years), juveniles (5–15 years), adult females (>15 years) and adult males (>15 years). We defined the applied categories on various age class systems for both elephant species (Arivazhagan and Sukumar 2008; Moss 2001; Pokharel et al. 2017). This sample consisted of 51 calves, 32 juveniles, 50 adult females and 30 adult males. For the African species, 121 photographs of the Amboseli National Park (Kenya; 2° 38´S, 37° 14´ E) population taken randomly between 2001 and 2016 were scored. This sample consisted of 29 calves, 28 juveniles, 40 adult females and 27 adult males. Both samples were balanced regarding age and sex category. We were unable to assess season for either free-ranging population, although seasonal changes in body condition do occur (De Klerk 2009; Foley et al. 2001; Ramesh et al. 2011; Ranjeewa et al. 2018).

Table 1. Body condition scores of the African elephant (*Loxodonta africana*) population in European zoos and a sample of their free-ranging counterparts in Amboseli National Park, Kenya

Age/sex category	N	Score range	Average ±SD	Median	First quartile	Third quartile
Calves (<5 years)**						
Zoo	12	6–8	7.15±0.69	7.00	7.00	8.00
free-ranging	29	5–8	6.39±0.79	6.00	6.00	7.00
Juveniles (5–15 years)**						
Zoo	48	5–8	6.45±0.71	6.00	6.00	7.00
free-ranging	28	5–8	5.89±0.74	6.00	5.00	6.00
Adult females (>15 years)***						
Zoo	108	1–9	6.90±1.19	7.00	6.00	8.00
free-ranging	40	5–8	6.03±0.85	6.00	5.00	6.75
Adult males (>15 years)(*)						
Zoo	21	6–8	6.67±0.75	7.00	6.00	7.00
free-ranging	27	5–8	6.33±0.83	6.00	6.00	7.00

Significant difference (U-test): *** P<0.001, ** P<0.01, * P<0.05; (*): P=0.054

Table 2. Body condition scores of the Asian elephant (*Elephas maximus*) population in European zoos and a sample of their free-ranging counterparts in Yala National Park, Sri Lanka

Age/sex category	N	Score range	Average ±SD	Median	First quartile	Third quartile
Calves (<5 years)***						
Zoo	49	4–9	6.59±0.98	7.00	6.00	7.00
free-ranging	51	3–7	5.39±0.92	5.00	5.00	6.00
Juveniles (5–15 years)***						
Zoo	69	5–9	6.72±1.16	7.00	6.00	7.00
free-ranging	32	3–7	5.25±0.89	5.00	4.75	6.00
Adult females (>15 years)***						
Zoo	179	3–9	6.58±1.29	7.00	6.00	7.00
free-ranging	50	3–7	5.30±1.02	5.00	5.00	6.00
Adult males (>15 years)*						
Zoo	29	4–8	6.21±0.98	6.00	6.00	7.00
free-ranging	30	2–7	5.53±1.04	6.00	5.00	6.00

Significant difference (U-test): *** P<0.001, ** P<0.01, * P<0.05

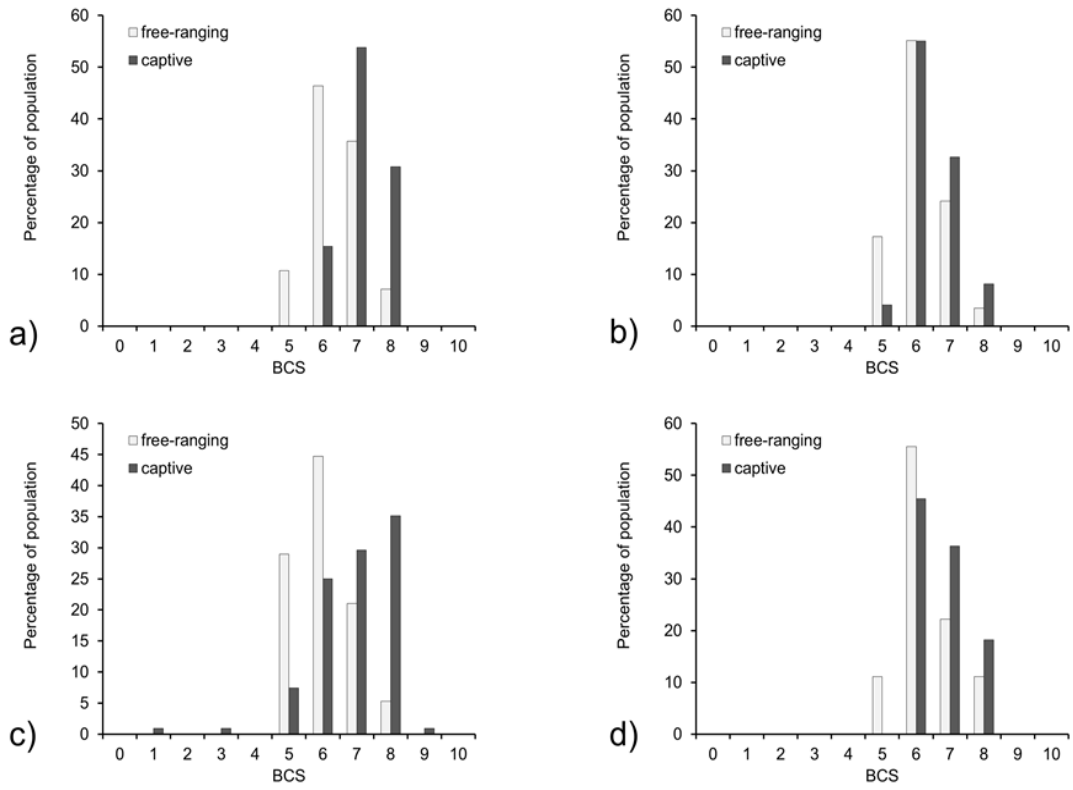

Figure 3. Distribution of body condition scores in populations of free-ranging (n=121) and captive (n=189) African elephants (*Loxodonta africana*). a) Calves (<5 years), b) Juveniles (5–15 years), c) Adult females (>15 years), d) Adult males (>15 years)

Comparison with literature data

Due to the differences in the BCS systems used in the literature, absolute scores were not directly comparable: for example, in a system with a score range of 1–5, a BCS of 5 indicates obesity, whereas it would indicate an intermediate state in a system with a score range from 1–10. In order to put our results into a comparative perspective, we compared our data (BCS range 0–10) to the data of Morfeld et al. (2016) (BCS range 1–5), equating our scores of 9–10 to their score of 5, our scores of 7–8 to their score of 4, etc. Additionally, we calculated a standardised score by expressing the mean or median score reported in publications as a proportion of the total score range, adjusting the range so that higher values indicate obesity. Thus, for example, a standardised score of 0.8 would indicate that the mean/median score was in the last (upper) quartile of the score range.

Statistical analysis

Body condition scores are non-parametric data by definition, and therefore, data should be represented by medians and quartiles; however, following recent convention (Chusyd et al. 2018; De Klerk 2009; Foley et al. 2001; Godagama et al. 1998; Harris et al. 2008; Kumar et al. 2014; Morfeld and Brown 2016; Morfeld et al. 2014; Morfeld et al. 2016; Ranjeewa et al. 2018; Somgird et al. 2016b; Wemmer et al. 2006), we additionally report means and standard deviations. To compare BCS of different groups, the Mann-Whitney U test was used. Correlations with quantitative measures were assessed by Spearman's correlation coefficient. This was done for the following parameters: age [years], group size [number of elephants sharing area], amount [all diet amounts are in estimated dry matter] concentrate fed [kg/day], amount bread fed [kg/day], amount fruit fed [kg/day], amount vegetables fed [kg/day], total amount fed (excluding roughage) [kg/day], feeding frequency [feedings/day], feeding enrichment [amount of different devices], amount training [minutes/day], enclosure area indoors [m2], outdoors [m2] and total enclosure area [m2]. More comprehensive evaluation was only performed in Asian elephant females, in which a variety of individual factors were correlated with the BCS; in this case, non-parametric correlations between the significant factors were analysed, and a General Linear Model was performed using ranked data. Statistical procedures were performed in SPSS 23.0.0 (IBM Corp., Armonk, NY), with the significance level set to 0.05.

Results

Collection of pictorial documents

In total, 64 different facilities maintaining 140 African and 228 Asian elephants were visited (all by CS), and elephants were photographed on site between beginning of January 2016 and the end of March 2017. Together with photographs received by

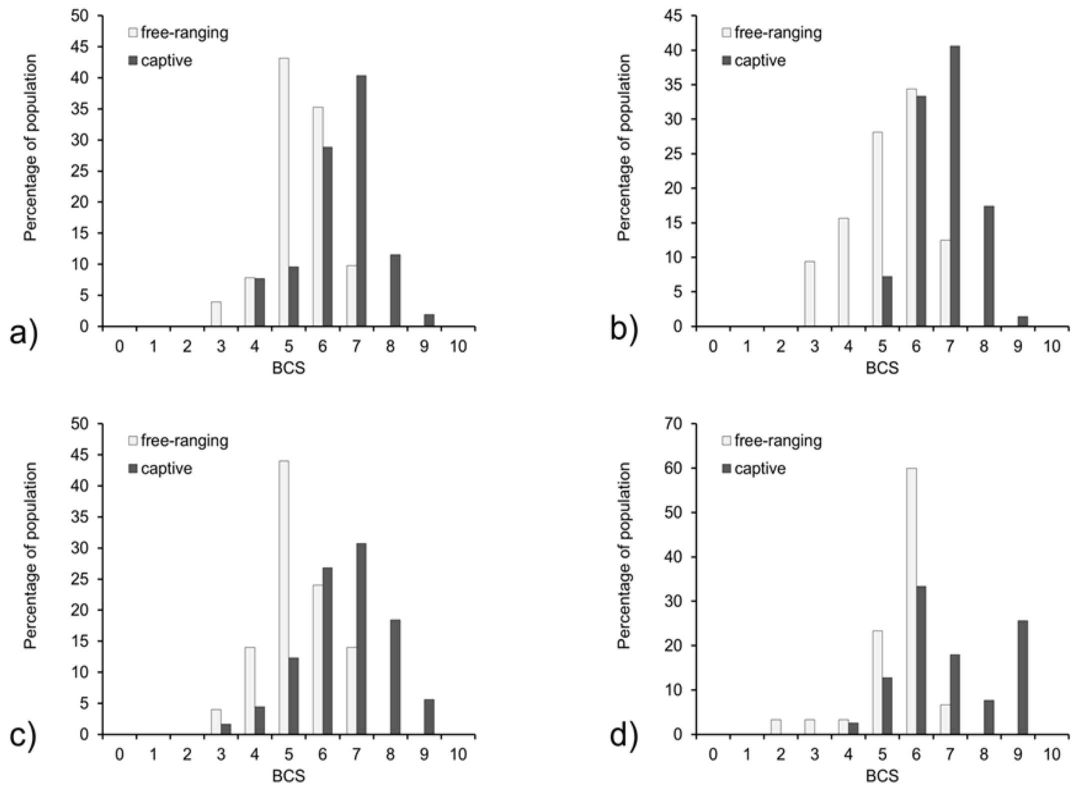

Figure 4. Distribution of body condition scores in populations of free-ranging (n=163) and captive (n=326) Asian elephants (*Elephas maximus*). a) Calves (<5 years), b) Juveniles (5–15 years), c) Adult females (>15 years), d) Adult males (>15 years)

mail, 192 African and 326 Asian elephants of European zoos were included in this study. This sample consisted mainly of elephants participating in the EEP´s (470/518; 91%), but elephants of non-member facilities (48/518; 9%) were included as well.

Life history data collection

Documentation and availability of life history and husbandry data varied considerably between institutions. As expected, comprehensive husbandry data were received only during on-site visits. Forty of the 64 visited facilities had a scale to weigh their elephants, and 35 of them conducted weight monitoring on a regular basis. Seven institutions had established body-condition scoring protocols, but only four of these zoos documented body scores with photos. While some facilities applied individual diet sheets for each elephant, others did not have any written document at all and it was up to the keepers how much of which ingredient was fed. Most institutions had some guidelines, which could be adapted by the keepers. Females were monitored much more closely for reproductive status than males, and most facilities used hormonal monitoring via urine or fecal testing. Only two institutions were found to accurately document musth behavior in their males. Investigation of potential correlation patterns between BCS and specific pathologies was not possible due to the diversity in the extent of available medical records.

Data analysis and check for repeatability

The intra-observer agreement generated identical scores in 366 cases (366/500; 73.2%) and a variance by 1 score in 132 cases (132/500; 26.4%). Thus, the repeatability in the range of maximally 1 scoring point was given in 99.6% of the pictures, which was considered acceptable for a protocol with a scoring range from 0 to 10.

Statistical analysis

Body condition scores, their distribution for the European zoo elephant population as well as both free-ranging samples are compiled in Tables 1 and 2 and Figures 3 and 4. Compared to their free-ranging counterparts, elephants kept in European zoos showed significantly higher scores ($P<0.05$). This was valid for all sex and age categories with the exception of adult African elephant males, in which the difference was marginally below the level of significance ($P=0.054$).

Within the captive population, there were significant species differences for all age classes; males (Asian mean: 6.21±0.98, median: 6.00, range: 4–8 vs. African mean: 6.77±0.75, median: 7.00, range: 6–7; $P=0.032$), females (Asian mean: 6.58±1.29, median: 7.00, range: 3–9 vs. African mean: 6.88±1.19, median: 7.00, range 1–9; $P=0.024$), calves (Asian mean: 6.59±0.98, median: 7.00, range: 4–9 vs. African mean: 7.15±0.69, median: 7.00, range 6–8; $P=0.045$), but not for juveniles (Asian mean: 6.73±0.89,

Table 3. Nonparametric correlation of husbandry parameters with body condition in African elephants (*Loxodonta africana*) kept in European zoos

Parameter tested	Calves (<5 years)	Juveniles (5–15 years)	Adult females (>15 years)	Adult males (>15 years)
Age [years]	R=0.14 ; P=0.660; n=13	R=-0.10; P=0.487; n=49	R=-0.00; P=0.968; n=108	R=0.19; P=0.410; n=22
Group size [n elephants sharing area]	n.a.	R=-0.09; P=0.715; n=20	R=-0.16; P=0.104; n=108	n.a.
Amount concentrate [kg*day]	n.a.	R=-0.12; P=0.535; n=31	R=0.12; P=0.389; n=58	R=0.22; P=0.443 n=14
Amount bread [kg*/day]	n.a.	R=-0.18; P=0.339; n=31	R=-0.27; P=0.042; n=58	R=-0.16; P=0.593; n=14
Amount fruit [kg*/day]	n.a.	R=0.34; P=0.061; n=32	R=-0.02; P=0.899; n=58	R=0.33; P=0.250; n=14
Amount vegetables [kg*/day]	n.a.	R=0.21; P=0.255; n=32	R=0.13; P=0.334; n=58	R=0.10; P=0.733; n=14
Total amount diet (excluding roughage) [kg*/day]	n.a.	R=-0.01; P=0.956; n=32	R=0.12; P=0.382; n=58	R=0.17; P=0.574; n=14
Feeding frequency [feedings/day]	n.a.	R=-0.23; P=0.258; n=27	R=-0.26; P=0.051; n=56	R=-0.35; P=0.266; n=12
Feeding enrichment [amount of different devices]	n.a.	R=0.03; P=0.874; n=32	R=-0.20; P=0.117; n=64	R=-0.57; P=0.034; n=14
Amount training [minutes/day]	n.a.	R=-0.25; P=0.188; n=30	R=-0.06; P=0.632; n=61	R=0.34; P=0.250; n=13
Enclosure area indoors [m2]	n.a.	R=0.45; P=0.041; n=21	R=-0.10; P=0.453; n=61	R=-0.13; P=0.697; n=11
Enclosure area outdoors [m2]	n.a.	R=0.13; P=0.477; n=33	R=0.02; P=0.891; n=73	R=-0.19; P=0.502; n=15
Total enclosure area [m2]	n.a.	R=0.20; P=0.405; n=20	R=0.03; P=0.841; n=57	R=-0.16; P=0.635; n=11

n.a.=not analyzed (n too low); in bold: significant correlations (P<0.05); * estimated dry matter

Table 4. Nonparametric correlation of husbandry parameters with body condition in Asian elephants (*Elephas maximus*) kept in European zoos

Parameter tested	Calves (<5 years)	Juveniles (5–15 years)	Adult females (>15 years)	Adult males (>15 years)
Age [years]	R=0.32; P=0.024; n=49	R=-0.22; P=0.073; n=69	R=0.09; P=0.258; n=179	R=-0.19; P=0.318; n=29
Group size [n elephants sharing area]	n.a.	R=-0.56; P=0.002; n=28	R=-0.22; P=0.003; n=179	n.a.
Amount concentrate [kg*/day]	R=-0.12; P=0.649; n=17	R=0.01; P=0.915; n=63	R=0.08; P=0.337; n=135	R=0.15; P=0.495; n=23
Amount bread [kg*/day]	R=0.11; P=0.674; n=17	R=0.06; P=0.629; n =63	R=-0.06; P=0.491; n=140	R=-0.07; P=0.754; n=24
Amount fruit [kg*/day]	R=0.29; P=0.259; n=17	R=0.386; P=0.002; n=63	R=0.10; P=0.239; n=139	R=0.44; P=0.032; n=24
Amount vegetables [kg*/day]	R=-0.11; P=0.672; n=17	R=0.07; P=0.623; n=60	R=0.20; P=0.018; n=139	R=0.47; P=0.023; n=23
Total amount diet (excluding roughage) [kg*/day]	R=0.04; P=0.871; n=17	R=0.09; P=0.489; n=63	R=0.07; P=0.428; n=141	R=0.32; P=0.122; n=24
Feeding frequency [feedings/day]	R=0.52; P=0.029; n=18	R=0.28; P=0.058; n=48	R=0.03; P=0.771; n=78	R=0.36; P=0.166; n=16
Feeding enrichment [amount of different devices]	R=0.31; P=0.177; n=21	R=0.34; P=0.018; n=49	R=-0.05; P=0.587; n=102	R=-0.17; P=0.492; n=19
Amount training [minutes/day]	R=-0.17; P=0.467; n=20	R=0.05; P=0.762; n=43	R=-0.12; P=0.255; n=93	R=0.37; P=0.136; n=18
Enclosure area indoors [m2]	R=0.08; P=0.742; n=21	R=0.05; P=0.679; n=62	R=-0.24; P=0.002; n=161	R=-0.24; P=0.243; n=26
Enclosure area outdoors [m2]	R=-0.11; P=0.620; n=23	R=-0.18; P=0.155; n=67	R=-0.23; P=0.003; n=165	R=0.01; P=0.955; n=28
Total enclosure area [m2]	R=-0.12; P=0.603; n=22	R=-0.13; P=0.317; n=62	R=-0.27; P=0.001; n=161	R=-0.02; P=0.949; n=26

in bold: significant correlations (P < 0.05); *:estimated dry matter

median: 7.00, range: 5–9 vs. African mean: 6.45±0.71, median: 6.00, range 5–8; P=0.061). Within species, there was no significant difference in BCS according to management system or the origin of elephants (wild caught vs. captive born) for any of the species/age groups. There were no significant differences between male and female adults within either species (data not shown). In neither species did scores differ between females that were cycling, pregnant, lactating or non-cycling. Additionally, we found no correlation between lactation status and BCS (data not shown). Breeding and non-breeding males of either species did not differ in BCS. However, in Asian adult females, currently breeding females (defined as having at least one offspring during the past 5 years or being currently pregnant) had significantly lower BCS (n=44, mean: 6.18±1.33, median: 6.00, range 3–9) than non-breeding females (n=108, mean: 6.71±1.25, median: 7.00, range 3–9; P=0.021). No such difference was observed in African females

Table 5. Comparison of body condition score distribution in recent population-wide assessments of North American and European zoo elephants

	Morfeld et al. (2016) North American population (mean age: 31.1 ± 13.7 years)					Present study European population (mean age: 34.9 ± 11.3 years)					
	African elephant (n=132)		Asian elephant (n=108)		Total		African elephant (n=130)		Asian elephant (n=218)		Total
Scoring range: 1-5	Female n=106	Male n=26	Female n=85	Male n=23	n=240	Scoring range: 0-10	Female n=108	Male n=22	Female n=179	Male n=39	n=348
Score	Percentage					Score	Percentage				
1	0	0	2.3	0	0.8	0-2	0.9	0	0	0	0.3
2	0	3.8	5.9	8.7	3.3	3-4	0.9	0	6.1	2.6	3.7
3	21.7	38.5	16.5	26.1	22.1	5-6	32.4	45.5	39.1	46.2	38.2
4	45.3	50.0	27.1	47.8	39.6	7-8	64.8	54.5	49.1	25.6	51.7
5	33.0	7.7	48.2	17.4	34.2	9-10	0.9	0	5.6	25.6	6.0

(P=0.619). Similarly, adult Asian females living in a breeding group had significantly lower BCS (n=98, mean: 6.39±1.31, median: 6.00, range: 3–9; P=0.022) than those not living in a breeding group (n=81, mean: 6.82±1.25, median: 7.00, range 4–9). Again, no such difference was evident in African females (P=0.941), or juveniles of either species. There were neither significant differences between non-breeders and previous breeders, nor between current and previous breeders, and there was no significant difference in any group depending on whether animals were weighed or BCS was applied regularly or not (data not shown). Results of non-parametric correlation tests between BCS and husbandry parameters are presented in Tables 3 and 4. For the African species, BCS in juveniles was positively correlated with indoor area, while for adult females and males, there was a significant

Table 6. Overview of research conducted on body condition scoring in African elephants (*Loxodonta africana*)

Living conditions	n	Investigated sex/age categories [years] ± SD	Standardized average score (average score/scoring range)	Correlating Parameters	Reference
free-ranging	240	all ages of both sexes	-	season	Albl (1971)
free-ranging	22	adult males only	-	stage of musth	Poole (1989)
free-ranging	not indicated	reproductively active females only	0.56-0.80 (mean)	season	Foley et al. (2001)
free-ranging	4-107 (depending on season and category)	all age classes females only	0.40-0.70 (mean)	season, nutritional resources, lactation	De Klerk (2009)
free-ranging	544	adults only	-	season, sex, history of translocation	Pinter-Wollman et al. (2009)
free-ranging	57	females only (10-45 years)	0.60 (median)	-	Morfeld et al. (2014)
free-ranging	124	all age classes of both sexes	0.56 (mean); 0.55 (median)	-	this study
semi-captive$_a$	7	juveniles of both sexes ; 10.7 ± 2.8	0.83 (mean and median)	-	Velthuizen (2008)
captive$_b$	not indicated	all age classes of both sexes	0.60 (mean)	handling method	Harris et al. (2008)
captive$_c$	50	females only (10-45 years)	0.80 (median)	captivity	Morfeld et al. (2014)
captive$_c$	132	both sexes, age not separately indicated for species	0.80 (mean and median)	sex, walking exercise, feeding schedule & methods	Morfeld et al. (2016)
captive$_c$	20	females; 34.75 ± 8.17	0.77 (mean); 0.80 (median)	age, body mass, fat mass	Chusyd et al. (2018)
captive$_d$	189	adults of both sexes; 30.7 ± 8.4	0.62 (mean); 0.64 (median)	-	this study

captive: investigated animals live in captivity; semi-captive: investigated animals live in semi-captive conditions in countries of origin; free-ranging: free-ranging individuals were investigated, a: elephant training facility in South Africa; b: UK zoos; c: North American zoos; d: European zoos

Table 7. Overview of research conducted on body condition scoring in Asian elephants (*Elephas maximus*)

Living conditions	n	Investigated sex/age categories; mean age [years] ± SD	Standardized average score (average score/scoring range)	Correlating parameters	Reference
free-ranging	-	not indicated	-	-	Fernando et al. (2009)
free-ranging	653	calves, juveniles, sub-adults and adults of both sexes	-	season, faecal glucocorticoid metabolites	Pokharel et al. (2017)
free-ranging	1622	calves, juveniles, sub-adults and adults of both sexes	-	season, sex	Ramesh et al. (2011)
free-ranging	27	not indicated	0.60 (median and mean)	-	Wijeyamohan et al. (2015)
free-ranging	3175 (containing 526 individuals at different times)	adult females, sub-adult and adult males	0.51 (mean)	reservoir water level, sex, age-size class in males	Ranjeewa et al. (2018)
free-ranging	163	all age classes of both sexes	0.49 (mean); 0.45 (median)	-	this study
semi-captive$_a$	119	All age classes of both sexes; age known for 50 elephants: 17.5 ± 1.8	0.61 (mean)	-	Wemmer et al. (2006)
semi-captive$_b$	42	all age classes of both sexes; 20.6 ± 17.7	0.35 (mean)	-	Harris et al. (2008)
semi-captive$_c$	22	mature females only; 29.4 ± 9.9)	0.73 (mean and median)	-	Thitaram et al. (2008)
semi-captive$_c$	5	adult males only; 41.4 ± 13.1	0.63 (mean); 0.75 (median)	-	Somgird et al. (2016a)
semi-captive$_d$	9	adult males only; 58.4 ± 8.6	0.69 (mean); 0.75 (median)	age, duration of musth Phase	Somgird et al. (2016b)
captive$_e$	140	all age classes of both sexes; 37.4 ± 1.4	0.58 (mean and median)	sex	Godagama et al. (1998)
captive$_f$	not indicated	all age classes of both sexes	0.58 (mean)	handling method	Harris et al. (2008)
captive$_g$	12	not indicated	0.69 (median)	rump fat thickness	Treiber et al. (2012)
captive$_h$	12	adults and juveniles of both sexes; 34.0 ± 15.6	0.60 (mean); 0.68 (median)		Kumar et al. (2014)
captive$_i$	10	adult and juvenile females of both sexes; 37 ± 19.93	0.57 (mean); 0.55 (median)	-	Romain et al. (2014)
captive$_g$	31	not indicated	0.80 (mean and median)	captivity	Wijeyamohan et al. (2015)
captive$_g$	108	both sexes, age not separately indicated for species	0.81 (mean); 0.8 (median)	sex, walking exercise, feeding schedule and methods	Morfeld et al. (2016)
captive$_j$	326	adults of both sexes; 37.6 ± 12.0	0.60 (mean); 0.64 (median)	captivity, breeding state, diet, enclosure size	this study

negative correlation of BCS with the amount of bread in the diet and the amount of feeding enrichment provided, respectively. In the Asian species, BCS in calves was positively correlated with age and feeding frequency. Juveniles and adult males showed both a positive correlation between BCS and amount of fruit in the diet, which also occurred for the amount of vegetables in the diet of adult females and males. Body condition scores in adult females were negatively correlated with the size of indoor, outdoor and total area.

Focusing on the various individual factors yielding a significant association with BCS in Asian females, group size was negatively correlated with the amount of vegetables fed (R=−0.50, P<0.001, n=139), and positively with living in a breeding group (R=0.79, P<0.001, n=179), being a breeder (R=0.38, P<0.001, n=179), and total enclosure area (R=0.23, P=0.002, n=179). Similarly, the total enclosure area was negatively correlated with the amount of vegetables fed (R=−0.29, P=0.001, n=136), positively with living in a breeding group (R=0.51, P<0.001, n=161) and positively with

Figure 5. Challenges encountered while scoring zoo elephant´s body condition: a) extraordinary hairiness, b) excessive hyperkeratosis, c) voluminous belly and d) well developed musculature

being a breeder (R=0.28, P<0.001, n=161). Using ranked data for BCS, the amount of vegetables fed and total enclosure area, a General Linear Model with BCS as dependent variable, group size, vegetables and area as covariates and living in a breeding group as a cofactor yielded a significant association with (ranked) total enclosure area only (F=11.320, P=0.001), whereas neither group size (F=0.187, P=0.666), the amount of vegetables fed (F=2.636, P=0.107) nor living in a breeding group (F=0.216, P=0.643) were significant.

Discussion

Reflection of our method

Data collection on site resulted in more comprehensive data especially concerning diet composition and management system than data collection via mail contact. Pictures of elephants taken by the author fulfilled the criteria to be included in 100% of the cases, whilst nearly 3.5% (5/150) of elephants for which pictures were received remotely did not pass this selection and were excluded from the study. Thus, elephants living in visited zoos might be overrepresented in our analysis. Ideally each elephant-keeping facility across Europe should have been visited, which was not feasible due to temporal and financial limitations. With respect to the data on the diets, it needs to be noted that amounts were based on the facilities' estimates of the amounts fed and not on actually measured intake data.

It can be questioned whether visual body condition scoring allows a reliable assessment of an elephant´s fat storage, because this method cannot consider intraabdominal adipose deposits. A recent study in horses detected a strong positive correlation between BCS and retroperitoneal fat score whilst no association between BCS and mesenteric or epicardial fat was found (Morrison et al. 2017). Whether this assumption is valid for elephants, too, will be hard to prove due to the lack of a method that allows assessment of intraabdominal fat deposits in a non-invasive way.

Although recommended as a management tool (Ward et al. 1999) and confirmed as viable by studies conducted in various species including elephants (Joblon et al. 2014; Morfeld et al. 2014; Morfeld et al. 2016; Pérez-Flores et al. 2016; Pettis et al. 2004; Pokharel et al. 2017; Wijeyamohan et al. 2015), BCS based on photographs has several limitations. First of all, standardisation regarding light conditions, ground planarity, movement and angle of the camera can be reached only to a certain extent. This limitation has been reported in cattle (Bewley et al. 2008) and might be even more pronounced in our work with respect to the significant variability between elephant-keeping facilities.

In order to reach the highest standardisation possible, the formulation of several criteria, which a photograph had to fulfill to be included in the study together with a strict selection process, were of paramount importance. During the scoring process two unexpected cases occurred, which led to the exclusion of further photographs. These were extraordinary hairiness and excessive hyperkeratosis in the lumbar region, prohibiting reliable scoring (Figures 5a and b).

Compared to the generally accepted protocol by Wemmer et al. (2006), our method focused on fewer body regions. However, these areas correlate strongest with subcutaneous measurements respectively serum triglyceride levels as indicators of fat storage in elephants (Albl (1971), Morfeld et al. (2014; 2016).

Individual animals have unique body proportions and fat distributions (Clements and Sanchez 2015), which may influence BCS and complicate comparisons between individuals. This aspect also seems valid in elephants, and consistent scoring was influenced by variance in an elephant´s individual appearance in many cases. This was especially true for elephants with a very voluminous belly or a prominent thoracic spine, where a vigilant effort was required to remain focused on the lumbar region (Figure 5c). Additionally, the visual scoring approach can hardly discriminate subcutaneous fat and well-developed musculature, which became obvious in elephant males (Figure 5d). Awareness of the musculoskeletal anatomy may reduce this limitation but cannot completely eliminate it. For pet species a muscle condition score (MCS) has been developed to be used complementary to body weight and BCS (Michel et al. 2011; Santarossa et al. 2017). Such systems are based on palpation, which would be impractical in elephants due to their size, thick skin and frequent inaccessibility. Nevertheless, we consider the scoring approach applied here to allow a reasonable ranking of animals.

The scoring of elephant calves represented another challenge. As mentioned before, the applied protocols have not been investigated concerning their applicability in sub-adult elephants. To our knowledge, no comparative research has been conducted in this field yet. Wijeyamohan et al. (2015) report their method to be applicable in elephants independent of sex and age, albeit they do not provide any evidence supporting this recommendation. Although our scoring method turned out to be independent of age, and the overall pattern of a difference between free-ranging and captive animals was also reflected in the calf data (Tables 1 and 2), we remain skeptical whether BCS can be meaningfully applied to growing animals. More insight in the validity of visual BCS in calves and juveniles might be gained by the comparison with growth curves. Hence, a long-term scoring approach combined with weight data would be more informative than our cross-sectional approach.

It remains unanswered how overweight, obesity and the ideal condition in elephants should be defined. For their 10-point scale, Wijeyamohan et al. (2015) do not define which score range is ideal. Morfeld et al. (2014; 2016) define score 3 in their 5-point scale as “ideal/normal”, while Treiber et al. (2012) consider a score from 4 to 7 in their 9-point scale preferable. Consequently for the scale applied here ranging from 0 to 10, a BCS between 4 and 6 could be considered ideal. These definitions are only based on the assumption that the middle range of an index represents a preferable condition. It should be noted that our data on free-ranging elephants indeed suggests that a BCS in the middle of the range, or slightly above it, appears to be the “normal” (Tables 6 and 7).

Scores of European zoo elephants

As intended, data collection and consequent scoring led to a comprehensive overview on BCS of the European zoo elephant population. Our goal to evaluate each zoo elephant in Europe was nearly reached with the evaluation of 97% (518/534). Similar to current results from North America, the majority of European zoo elephants in both species had elevated BCS with 57.7% of the population in the scoring range of 7–10. This percentage is lower compared to the results from North America (73.8%, Table 5).

Relation to findings from previous research

Comparing the average proportions of scoring ranges of individual studies, six studies conducted on African elephants in (semi-) captivity revealed consistently standardised scores of at least 0.6, including three reports with a mean/median of at least 0.8 of the score range. In contrast, research on free-ranging African elephants demonstrated in four out of four cases values of maximally 0.6, with two reports showing higher scores exceptionally during seasons with high primary productivity (De Klerk 2009; Foley et al. 2001). Thus, our findings are in accordance with the literature in reporting higher scores in captive compared to free-ranging African elephants (Table 6).

In nine out of 13 studies investigating Asian elephants in (semi-) captivity, the mean/median BCS was >0.6 of the score range, whereas data on free-ranging Asian elephants reported by Wijeyamohan et al. (2015) and Ranjeewa et al. (2018) had a mean/median of 0.6 respectively 0.51 and our results do not even reach 0.5 (mean: 0.49 and median: 0.45). Our study thus corroborates findings from the literature with higher scores in captive compared to free-ranging populations of the Asian elephant (Table 7).

For wild elephants, body condition scores are affected by seasonal changes in resource availability (Foley et al. 2001; Pokharel et al. 2017; Ranjeewa et al. 2018; De Klerk 2009). Using a sample originating from one of the most extensively studied and best protected elephant populations across Africa, namely in Amboseli National Park, we tried to prevent an overestimation of the difference between captive and free-ranging conditions. Amboseli elephants do fluctuate in body condition but this environment is much less extreme than other habitats, and score changes in a normal (non-drought) year are considered to be minimal (Amboseli Elephant Project, long term data). Similarly, we used a sample from the long-term studied population in Yala National Park for the Asian species.

It is unknown whether the difference in BCS between free-ranging and captive elephants is principally caused by a calorific oversupply or by lack of physical activity. The amount and quality of zoo diets are usually not season-dependent and are more energy-rich compared to natural foods, which might predispose zoo elephants for higher BCS (Hatt and Clauss 2006). Although we cannot explain the negative correlation of BCS with amount of bread fed to female African elephants, the positive correlation of BCS with the amount of fruits and vegetables fed to adult and juvenile Asian elephants supports the above-noted assumption (Table 4). Moreover, the influence of an unnatural energy-rich diet on body condition has been reported in further wildlife species (Heidegger et al. 2016; McWilliams and Wilson 2015; Scheun et al. 2015; Wright et al. 2011). Walking distance in some zoo elephants has been shown to be similar to the situation in the wild (Holdgate et al. 2016; Rowell 2014) although there might be considerable variation between facilities. Results from previous research in the UK and North American zoo population did not reveal any correlation of BCS with daily walking distance (Harris et al. 2008; Holdgate et al. 2016). We were not able to detect a correlation of BCS with staff-directed exercise, as reported by Morfeld et al. (2016). Due to the trend for a shift from direct contact to protected contact in European zoos (EEG 2017), only a few facilities remain that practice staff-directed walking of their elephants. However, a correlation of BCS with management system could also not be detected. This finding corroborates results from North America (Morfeld et al. 2016), but is in contrast to Harris et al. (2008) who reported significantly lower scores for UK zoo elephants managed in free contact. Authors of the latter study do not hypothesise whether this correlation might be caused by staff-directed exercise. In adult Asian elephant females we detected a significant negative correlation of BCS with enclosure size (Table 4). This correlation was not found by Morfeld et al. (2016), but may support the intentions of modern zoos to build larger facilities to further improve elephant welfare. To investigate the influence of such measures in a proper way, a long-term study regarding the development of BCS over time would be more appropriate than our cross-sectional approach applied here. Compilation of comprehensive health data would be important to allow the investigation of potential correlation patterns regarding zoo elephant welfare.

The significantly higher scores found in African elephants compared to their Asian counterparts in European zoos have not been reported yet. Harris et al. (2008) and Morfeld et al. (2016) did not find any difference in BCS between the two elephant species. In contrast to the recent study of the North American zoo population by Morfeld et al. (2016), we could not find any significant correlation between BCS and sex. Neither did differences correlate with reproductive or lactation status. According to findings from previous research in free-ranging populations (Albl 1971; De Klerk 2009; Ramesh et al. 2011), significant differences depending on reproductive and lactation status were expected. Their absence is in accordance with the report from Thitaram et al. (2008) and can be explained by additional nutritional supply of lactating females in captivity, which might cover their increased needs and maintain a stable condition, or the inappropriateness of our cross-sectional study design to detect BCS changes over the course of lactation. On the other hand, we found significantly lower scores in currently breeding adult Asian females compared to non-breeders, and the difference was also significant when all females living in a breeding group (regardless of whether or not the individual animal was breeding) were considered. Such a result would in theory match previous findings in African elephants (Freeman et al. 2009; Morfeld and Brown 2016), black rhinoceros (*Diceros bicornis*) (Edwards et al. 2015) and Asian greater one-horned rhinoceros (*Rhinoceros unicornis*) (Heidegger et al. 2016) that females with a higher body condition score have a lower reproductive viability. However, the finding of Freeman et al. (2009) of a positive correlation of a body mass index (kg/m2) used as indicator of physical condition with the risk to be acyclic in captive African elephant females was not corroborated in either species in the present investigation, which is in accordance to the findings of Chusyd et al. (2018). The interrelationships between breeder status, group size, diet and enclosure size in the present study did not allow identifying a simple causation. Leighty et al. (2009) suggested social complexity and breeding to increase walking rates in zoo elephants, which might explain lower BCS in larger groups that breed and have larger enclosures at their disposal. However, enclosure area might be a surrogate measure for the general investment (in terms of various resources) and other management measures that lead to positive effects for elephant BCS.

Although no indicators of health status have been shown to correlate with BCS in captive elephants yet (Miller et al. 2016), foot disorders and degenerative joint disease in (older) elephants should in theory be exacerbated by high BCS, as suggested by Fowler and Mikota (2006). In other species, reduced longevity and life quality of obese individuals is documented, such as orangutans (*Pongo spp.*) (Cocks 2007), pet dogs (Yam et al. 2016) as well as humans (Samaras and Elrick 2002). Additionally, Heidegger et al. (2016) suggest the occurrence of leiomyomas in captive female greater one-horned rhinos to be linked with obesity; these authors also review some of the pertinent literature for humans. It would be interesting to assess whether this is also true in Asian elephants that often suffer from uterine leiomyoma (Aupperle et al. 2008; Lueders et al. 2010; Sanchez et al. 2004), and which role a potential gene mutation reported in humans may play (Heinonen et al. 2014).

These considerations lead to the recommendation that regular monitoring of weight and body condition, and the implementation of measures that maintain an intermediate rather than an obese body condition, are important in captive elephants. This is not only important with respect to their health in general, but as well to successful breeding. Although the latter may be heavily influenced by factors like availability of appropriate males and herd constellations (Töffels 2015; Wiese and Willis 2006), we consider monitoring of female elephant´s condition an important cue to increase breeding success, which is in accordance with Freeman et al. (2009). This is especially true for the captive population of African elephants which is not self-sustaining (Schwammer and Fruehwirth 2015; Schwammer and Fruehwirth 2016). In long-lived species such as elephants, long-term monitoring is required to reliably detect factors influencing husbandry success with emphasis on their health and welfare.

In conclusion, validated protocols served as practical tools for population-wide visual body condition scoring of European zoo elephants. In accordance with previous research, zoo elephants of both species had significantly higher BCS compared to samples from free-ranging populations. Compared to current population data from North America, zoo elephants in Europe show a trend towards a more ideal scoring range. A near ideal BCS is an aim to strive for as part of welfare in the husbandry of elephants and as such further improvement regarding the diet are warranted for the captive elephant population. To monitor the influence and effectiveness of such adaptations, visual body condition scoring in a long-term approach might present a reliable tool.

Acknowledgements

We acknowledge all elephant-facilities visited as well as the ones who provided data remotely for their precious support. EAZA, BIAZA and both EEP-coordinators are acknowledged for their endorsement of our project. We wish to thank all the persons providing current photographs from zoo elephants across Europe, especially Jonas Livet, Vincent Manero, Petra Prager and Klaus Rudloff, as well as Dr. Cynthia Moss and the Amboseli Trust for Elephants for providing photographs of free-ranging African elephants, Dr. Vicki Fishlock for very valuable comments on previous versions of the manuscript, Jeanne Peter for example drawings for our scoring protocol, and Zoo Zurich, Zoo Basel and the Karl und Louise Nicolai-Stiftung for funding this research.

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