JZAR www.jzar.org JOURNAL OF ZOO AND AQUARIUM RESEARCH

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JZAR Review article

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Review article

Visual body condition scoring in zoo animals – composite, algorithm and overview approaches in captive Asian and African elephants

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Keywords:
body condition scoring (BCS), *Elephas maximus*, *Loxodonta africana*, weight monitoring, zoo animal

Article history:
Received: 2 July 2016
Accepted: 20 January 2017
Published online: 31 January 2017

Abstract:
Various body condition scoring (BCS) methods have been developed as management tools in zoo animal husbandry. In contrast to BCS for farm animals, where visual and palpable features are used, these protocols are mainly restricted to visual cues. Considering their inherent subjectivity, such methods face scepticism as their reliability is questioned. In terms of their respective methodology, composite BCS (where individual body regions are scored and a sum or mean is calculated), algorithm BCS (where a score is achieved by following a flow chart) and overview BCS protocols (where a score is given based on overall appearance) can be distinguished. In order to compare their practicability and consistency, we conducted a test with veterinary students (n=18) scoring an equal number (n=15) of African (*Loxodonta africana*) and Asian elephant (*Elephas maximus*) photographs using three different protocols. The composite approach showed least inter-observer consistency, while the overview protocol led to the highest differentiation of individual elephant condition. When regularly assessed, visual body condition scoring may serve as an important tool for the health surveillance and complete the medical history of individual zoo animals. Nonetheless, a validation process for each protocol developed should be carried out before its application. Further research might concentrate on long-term, individual-based body condition monitoring, using archives of standardised photographs.

Introduction

The assessment of body condition is an important tool in various animal management systems, whether one manages free-ranging populations, domesticated farm animals or captive zoo animal species. While economic interest motivates the practice in production animals, animal health issues are the motivation in scoring pets (Laflamme 2012). A high proportion of companion animals suffer from obesity (Laflamme 2012), and obesity has been a concern in zoo animal husbandry as well. Under the conditions of captivity several wildlife species are known to be prone to obesity (e.g. equids (Bray and Edwards 1999), tapirs (Clauss et al. 2009), rhinos (Clauss et al. 2005), elephants (Morfeld et al. 2014) and monogastric primates (Dierenfeld 1997; Terranova et al. 1997; Videan et al. 2007)), but there are also examples such as giraffe (Potter and Clauss 2005) and moose (Clauss et al. 2002), in which poor body conditions seem to occur more frequently. Moreover, body condition scoring systems are used extensively by ecologists investigating wild populations and their interaction with restricted resources or changing environments (DelGiudice et al. 2011; Lane et al. 2014; Carpio et al. 2015; McWilliams and Wilson 2015).

In order to achieve the most accurate estimation of an animal´s physical condition, a number of different scoring methods have been developed, such as the kidney fat index, bone marrow fat index (Jakob et al. 1996; Cook et al. 2007), bioelectrical impedance analysis, and morphometric measurements such as weight, size, circumferences and ratios from these values (Barthelmess et al. 2006; Pitt et al. 2006; Peig and Green 2009). Production and hunted animals can be scored by invasive non-repeatable techniques at slaughter, including fresh-carcass weight or fat indices, and also with non-invasive methods such as morphometric measurements and visual scores. For the monitoring of pets, only non-invasive repeatable techniques seem adequate. Although post mortem information is important in zoo animals, *in vivo* information is required to facilitate the optimisation of care and management circumstances (Ward et al. 1999).

Individuals typically differ in body mass, depending not only on their nutritional status, but on their phenotype. To account for this, mass measurements are typically related to a geometric body measure such as length or area. In humans this is done by the calculation of the so-called body mass index (BMI), a ratio of body mass and stature in metres squared (e.g. Foster et al. 2012). In animals, various species-specific measurements have been used in order to obtain similar ratios, using body mass against, for example, total length in geese (Halse 1984), limb length in kangaroos (Moss and Croft 1999), carapace length in tortoises (Furrer et al. 2004), wing length in penguins (Clements and Sanchez 2015), body length in raccoons (McWilliams and Wilson 2015), and shoulder height in rhinos (Heidegger et al. 2016). While these studies tried to readjust body mass using further geometric measurements, formulae have been developed to calculate body mass from body length, shoulder height and chest girth in Asian elephants (Kurt and Nettasinghe 1968; Sreekumar and Nirmalan 1989).

These methods show variable practicability depending on the purpose of the assessment and the population concerned. Most of them are post mortem measurements and thus not helpful for the monitoring of live animals. For the latter, a less invasive technique such as the body condition score (BCS) is warranted. While such a system may consider palpable and visual cues in domesticated or tamed individuals, it is restricted to the visually detectable ones in most wildlife species (Bray and Edwards 1999). Lacking these limitations, the existence of an established system for almost every domesticated animal species seems unsurprising (cattle (Wildman et al. 1982), horses (Henneke et al. 1983; Kienzle and Schramme 2004), sheep (Russel 1984), pigs (DEFRA 1998), dogs (Laflamme 1997), buffaloes (Alapati et al. 2010) and goats (Vieira et al. 2015)).

Focusing on wild and zoo animals, a visual body condition scoring system will not be viable for every species. For example, birds are usually not scored by a visual method because their plumage covers benchmarks of the body shape such as bony protuberances and muscular contours. Nevertheless, the usefulness of such an index has been demonstrated in geese (Owen 1981) and Magellanic penguin (*Spheniscus magellanicus*) (Clements and Sanchez 2015). The extraordinarily flat and dense coat of geese and penguins facilitates the use of a visual score in these species.

In mammalian species, visual characteristics alone do not necessarily provide reliable results, either. According to Gerhart et al. (1996), the dense hair coat of caribou prevents any visual evaluation of body contours, while in ungulates originating from warmer climatic regions the practicability of visual body condition scoring systems has been extensively documented (Riney 1960; Gallivan et al. 1995; Ezenwa et al. 2009; Wright et al. 2011; Taylor et al. 2013). Animals with short or no hair are obviously well-suited for an assessment based on visual cues. Thus multiple species-specific protocols have been developed and shown to be useful under field conditions for rhinos (Keep 1971; Reuter and Adcock 1998, Heidegger et al. 2016), tapirs (Clauss et al. 2009) and elephants (Poole 1989; Wemmer et al. 2006; Fernando et al. 2009; Morfeld et al. 2014, 2016; Wijeyamohan et al. 2014).

Independent of the species investigated, the benefits of a visual BCS system are its practicability, simplicity and the low costs. Moreover, according to Bray and Edwards (2001), Reppert et al. (2011) and Clements and Sanchez (2015), a numerical BCS can facilitate communication amongst care teams and hence improve management of an animal species in a zoo setting.

The visual approach

Following the structure of the earliest established scoring systems for farm animals (Wildman et al. 1982; Henneke et al. 1983), most of the existing protocols consist of five or more categories, where a score of one represents the poorest and five the highest body condition. For each score, the indices provide a description, commonly combined with an example photograph or drawing. In zoo animal species, the pictorial part is often emphasised due to its practicability under field conditions, where time to read is often not ensured and the individual under investigation has to be categorised at a glance (Riney 1960; Fernando et al. 2009; Morfeld et al. 2014). Depending on the level of differentiation, a system may allow increments at 0.5-intervals or full numbers only. The latter is often the case in BCS comprising more than five categories, while the former is common in five-point scales. Besides the direct assessment, describing a category for every single score, some indices propose an indirect evaluation. In doing so, every other condition is defined by lying between the two neighbouring ones (e.g. Fernando et al. 2009).

Because of its acceptance as a tool in the weight management of zoo animals (Ward et al. 1999; Bray and Edwards 1999), several species-specific visual scoring systems have already been developed. Their similarities and differences are listed in Table 1. With respect to practicability of a visual scoring system, the body areas evaluated need to be easily visible. This is shown in the pioneering protocol by Riney (1960) as well as in the subsequent indices developed for further wild and zoo animal species (Reuter and Adcock 1998; Wemmer et al. 2006; Dierenfeld et al. 2007; Clauss et al. 2009; Fernando et al. 2009; Wright et al. 2011; Morfeld et al. 2014; Wijeyamohan et al. 2014). All these systems mainly emphasise anatomical characteristics of the hind half of the body such as tail head, backbone, pelvic bone and ribs (see also Table 1). Several species-specific indices have been adapted and optimised by validation studies, whereby regions showing high correlation with direct or indirect quantitative measurements of body fat remained in the protocol, while others were excluded. For example, Morfeld et al. (2014) investigated body areas in African elephants previously suggested by Wemmer et al. (2006) to be relevant in Asian elephants. These authors correlated the visual scores with subcutaneous fat measurements in the same animals, and excluded regions for which no strong correlation could be determined (e.g. head, shoulders). According to this methodology, any scoring system should have gone through such a validation process in order to ensure reliable and consistent results (Cook et al. 2001b; Barthelmess et al. 2006; Pitt et al. 2006; Peig et al. 2009). Scoring body areas not highly correlating with an established gold standard might provide misleading results (Cook et al. 2001b). Apart from the aforementioned species-specific morphometric measurements, several validation techniques can be used in a number of taxa. These are the determination of the amount of subcutaneous fat by ultrasonography (Cook et al. 2001a; Stringer et al. 2010; DelGiudice et al. 2011; Reppert et al. 2011; Treiber et al. 2012; Morfeld et al. 2014), bioelectrical impedance analysis (Barthelmess et al. 2006; Pitt et al. 2006), measurement of serum triglyceride levels (Morfeld et al. 2016), direct measurement of body fat content (Cook et al. 2001b, 2007) or the amount of kidney fat (Ezenwa et al. 2009; Carpio et al. 2015). In addition to limitations due to species-specific characteristics (mainly thick and dense hair) covering the critical anatomical benchmarks, visual scoring can be influenced by various factors. These include the intestinal tract filling and hydration status (Reuter and Adcock 1998), the reproductive stage in females (Dierenfeld et al. 2007; Ezenwa et al. 2009; Reppert et al. 2011) or an increased inter-observer variability due to the subjective character of the technique. The latter can be

Table 1. Overview of specific body condition score protocols published for wild and zoo animal species.

Species	Critical body areas	Body regions scored individually	Defined categories (range of mean score)	Example pictures/ drawings provided	Reference
Barnacle geese (*Branta leucopsis*)	abdominal profile	– (only one single area scored)	4 (1–4)	yes	Owen (1981)
Magellanic penguin (*Spheniscus magellanicus*)	pectoral muscle, keel, ventrum, back, hips, furcula, shoulder	no	5 (1–5)	yes	Clements et al. (2015)
Cheetah (*Acinonyx jubatus*)	neck, shoulders, abdomen, tail head, pelvis, ribs	no	5 (1–5)	yes	Dierenfeld et al. (2007)
Cheetah (*Acinonyx jubatus*)	shoulder, torso, topline, point of hip, hip angle, tail head, point of buttocks, hind leg	no	9 (1–9)	yes	Reppert et al. (2011)
Kinkajou (*Potos flavus*)	ribs, abdomen, hips, shoulder, tail, skull	no	5 (1–5)	yes (but only partially)	Wright and Edwards (2009)
Polar bear (*Ursus maritimus*)	vertebrae, ribs, hip bones	no	5 (skinny, thin, average, fat, very fat)	yes	Stirling et al. (2008)
Black rhinoceros (*Diceros bicornis*)	neck, shoulder, ribs, spine, rump, abdomen, tail base	yes (not imperative, but recommended)	5 (1–5)	yes	Reuter and Adcock (1998)
Greater one-horned rhinoceros (*Rhinoceros unicornis*)	neck, shoulder, ribs, spine, abdomen, rump, tail base	yes	5 (1–5)	yes	Heidegger et al. (2016)
Tapirs (*Tapirus indicus* and *Tapirus terrestris*)	ribs, back, neck, shoulders, tail head, hips	no	5 (1–5)	yes	Clauss et al. (2009)
Baird´s tapir (*Tapirus bairdii*)	head, neck, shoulder, ribs, spine, pelvis	yes	25 (6–30)	yes	Pérez-Flores et al. (2016)
Various ungulate species	tail, pelvic girdle, croup, backbone, ribs	no	3 (good, medium, poor)	yes	Riney (1960)
African buffalo (*Syncerus caffer caffer*)	ribs, spine, hips, tail, coat	yes	5 (1–5)	no	Ezenwa et al. (2009)
Eastern bongo (*Tragelaphus eurycerus isaaci*)	neck, shoulders, withers, loin, back, tail head, hips, ribs	no	5 (1–5)	yes	Wright et al. (2011)
Greater kudu (*Tragelaphus strepsiceros*)	neck, shoulder, ribs, back, hip, tail head	no	5 (1–5)	yes	Taylor et al. (2013)
Giant anteaters (*Myrmecophaga tridactyla)*	neck, shoulder, hip, tail, head	no	5 (1–5)	yes	Clark et al. (2016)
Large hairy armadillo (*Chaetophractus villosus*)	jaw, body shell, hips, thighs	no	5	yes	Clark et al. (2016)
Yellow/six-banded armadillo (*Euphractus sexcinctus*)	jaw, body shell, hips, thighs	no	5	yes	Clark et al. (2016)
Southern three-banded armadillo (*Tolypeutes matacus*)	jaw, body shell, hips, thighs	no	5	yes	Clark et al. (2016)
Aardvarks (*Orycteropus afer*)	neck, shoulder, hip, tail head	no	5 (1–5)	yes	Clark et al. (2016)
Dromedary camel (*Camelus dromedaries*)	ribs, ischial and coxal tuberosities, scapula, vertebrae, flank, recto-genital zone	no	6 (0–5)	yes	Faye et al. (2001)
African elephant (*Loxodonta africana*)	shoulder blade, pelvic bone, backbone, belly	no	6 (1–6)	no	Poole (1989)
African elephant (*Loxodonta africana*)	backbone, pelvic bone, ribs	no	5 (1–5)	yes	Morfeld et al. (2014)
Asian elephant (*Elephas maximus*)	head, scapula, ribs, flank, lumbar vertebrae, pelvic bone	yes	12 (0–11)	yes (but only partially)	Wemmer et al. (2006)
Asian elephant (*Elephas maximus*)	ribs, shoulder and pelvic girdle, backbone, neck	no	11 (0–10)	yes	Fernando et al. (2009)
Asian elephant (*Elephas maximus*)	ribs, scapula, pelvic bone, vertebral column	no	10 (1–10)	yes	Wijeyamohan et al. (2014)
Asian elephant (*Elephas maximus*)	backbone, pelvic bone, ribs	no	5 (1–5)	yes	Morfeld et al. (2016)

Table 2. Overview of reported correlation patterns of visual scoring systems with other body condition indices. *c:* investigated animals live in captivity, *f:* free-ranging individuals were investigated.

Species	Correlating body condition index	Type of correlation	Remarks	Reference
Barnacle geese (*Branta leucopsis*)	weight/wing length ratio	positive, linear	–	Owen (1981)
Magellanic penguin (*Spheniscus magellanicus*)	weight/wing length ratio	positive	–	Clements et al. (2015)
Cheetah (*Acinonyx jubatus*)	body mass	positive, linear	significant only in adult individuals	Reppert et al. (2011)
Polar bear (*Ursus maritimus*)	mass/length^2 ratio	positive	significant	Stirling et al. (2008)
Polar bear (*Ursus maritimus*)	adipose lipid content	positive	significant	Stirling et al. (2008)
Greater one-horned rhinoceros (*Rhinoceros unicornis*)	body mass/shoulder height ratio	positive	–	Heidegger et al. (2016)
Baird´s tapir (*Tapirus bairdii*)	neck circumference	positive	significant	Pérez-Flores et al. (2016)
Baird´s tapir (*Tapirus bairdii*)	thorax circumference	positive	significant	Pérez-Flores et al. (2016)
African buffalo (*Syncerus caffer caffer*)	kidney fat	positive	not detected in females	Ezenwa et al. (2009)
African buffalo (*Syncerus caffer caffer*)	haematocrit	positive	–	Ezenwa et al. (2009)
Yellow/six-banded armadillo (*Euphractus sexcinctus*)	body mass	positive	–	Clark et al. (2016)
African elephant (*Loxodonta africana*)	subcutaneous fat thickness	positive	investigation on female elephants only; strongest correlation for the vertebral ridge	Morfeld et al. (2014)
Asian elephant (*Elephas maximus*)	subcutaneous fat thickness	positive, linear	measured by ultrasound	Treiber et al. (2012)
Asian elephant (*Elephas maximus*)	muscle and muscle + fat thickness	positive, linear	measured by ultrasound	Treiber et al. (2012)
Asian elephant (*Elephas maximus*)	weight/morphometric measurement ratios	positive	measurements taken: height, neck girth, chest girth, hind girth	Wijeyamohan et al. (2014)
Asian elephant (*Elephas maximus*)	skin fold measures	positive	various hanging skin folds measured	Wijeyamohan et al. (2014)
Asian elephant (*Elephas maximus*)	serum triglyceride levels	positive	significant, except for the scores 2 and 3	Morfeld et al. (2016)

minimised if scoring is conducted by a single person (Stringer et al. 2010). Besides the validation of visual-based scoring systems, their correlation patterns with further body condition indices have been investigated and reported (for an overview see Table 2). Furthermore, researchers have succeeded in demonstrating correlation patterns of various parameters with visual body condition scores (compiled in Table 3). Once developed and validated, a visual body condition scoring system can be applied by direct observation or the evaluation of pictorial documents (Ward et al. 1999; Morfeld et al. 2014; Wijeyamohan et al. 2014). Using the latter indirect method of observation, standardisation of the photographs investigated should be considered, in order to allow a reliable assessment (Morfeld et al. 2014). The required level of standardisation depends on the purpose of the study and the species-specific recognisability of the critical body regions (Fernando et al. 2009; Reppert et al. 2011; Morfeld et al. 2014). Apart from differences concerning validation and kind of observation, indices do vary in the way the BCS is obtained. This can be demonstrated in elephants.

Comparison of visual BCS approaches

Composite body condition scoring

Following the protocol by Wemmer et al. (2006), six anatomically distinct characteristics are point-scored and subsequently totalled to obtain the index (Table 1). Thus, each body area is given the same influence on the mean score, with the exception of the flank region, contributing at most one point. A similar approach is to score each body region separately using the entire scale (most often 1–5) with subsequent calculation of a mean value. This has been applied in rhinos by Reuter and Adcock (1998) and Heidegger et al. (2016).

Algorithm body condition scoring

In contrast, Morfeld et al. (2014) and Wijeyamohan et al. (2014) presented an algorithm or flowchart-like guide, emphasising the ribs, scapula and pelvic bone, while the backbone is used for subordinate staging. Therefore, if ribs are visible in an elephant, the flow chart leads to a BCS of 1 independently of the backbone´s

Table 3. Overview of reported correlation patterns of visual body condition scores with other parameters in free-ranging (*f*) and captive (*c*) individuals.

Species	Correlating parameters	Type of correlation	Remarks	Reference
Barnacle geese (*Branta leucopsis*) *f*	feeding on high-energy foods	positive	correlation demonstrated in both directions (BCS increases when food available)	Owen (1981)
Pink-footed geese (*Anser brachyrhynchus*) *f*	harshness of preceding winter	negative	–	Clausen et al. (2015)
Pink-footed geese (*Anser brachyrhynchus*) *f*	individual spring-fattening rates	inversely proportional	only in early spring	Clausen et al. (2015)
Polar bear (*Ursus maritimus*) *f*	season	higher in autumn	except females with cubs	Stirling et al. (2008)
Polar bear (*Ursus maritimus*) *f*	female reproductive status	adult females with cubs in poorer condition than solitary ones	–	Stirling et al. (2008)
Eastern black rhinoceros (*Diceros bicornis michaeli*) *c*	female reproductive status	higher in nulliparous females compared to parous ones	European zoos	Edwards et al. (2015)
Greater one-horned rhinoceros (*Rhinoceros unicornis*) *c*	total estimated dry amount of diet	positive	–	Heidegger et al. (2016)
Greater one-horned rhinoceros (*Rhinoceros unicornis*) *c*	amount of fruits and vegetables in diet	positive	correlation approached significance	Heidegger et al. (2016)
Tapirs (*Tapirus indicus, Tapirus terrestris*) *c*	digestible energy intake	positive	–	Clauss et al. (2009)
Tapirs (*Tapirus indicus, Tapirus terrestris*) *c*	faecal consistency	negative (softer faeces in tapirs with higher BCS)	–	Clauss et al. (2009)
Tapirs (*Tapirus indicus, Tapirus terrestris*) *c*	occurrence of colic	positive	small sample size (four tapirs)	Clauss et al. (2009)
Baird´s tapir (*Tapirus bairdii*) *c* and *f*	captive vs free-ranging	higher in captive compared to free-ranging tapirs	–	Pérez-Flores et al. (2016)
Impalas (*Aepyceros melampus*) *f*	season	poor in winter and spring, good in summer	variation was clearest in lambs and yearlings; nursing females showed a contrary correlation pattern	Gallivan et al. (1995)
Moose (*Alces alces*) *f*	sex	lower in males compared to females	might depend on seasonal activity patterns	DelGuidice et al. (2011)
Greater kudu (*Tragelaphus strepsiceros*) *c*	dry matter intake and intake of metabolisable energy	positive	small sample size	Taylor et al. (2013)
Aardvarks (*Orycteropus afer*) *c*	amount of dry matter offered	negative	small sample size	Clark et al. (2016
African elephant (*Loxodonta africana*) *f*	stage of musth	body condition decreases during musth phase	–	Poole (1989)
African elephant (*Loxodonta africana*) *f*	duration of musth	negative, linear	–	Poole (1989)
African elephant (*Loxodonta africana*) *c and f*	captive vs free-ranging	significantly higher in captive elephants	investigation on female elephants only	Morfeld et al. (2014)
Asian elephant (*Elephas maximus*) *f*	season	decrease in body condition during dry season	significant differences between age-classes	Ramesh et al. (2011)
Asian elephant (*Elephas maximus*) *f*	sex	lower body condition in males	demonstrated for adult elephants only	Ramesh et al. (2011)
Asian elephant (*Elephas maximus*) *c*	sex	higher scores in females	–	Morfeld et al. (2016)
Asian elephant (*Elephas maximus*) *c*	staff-directed walking exercise	decreased risk for higher scores	only significant if exercise exceeds 14 hours per week	Morfeld et al. (2016)
Asian elephant (*Elephas maximus*) *c*	unpredictable feeding schedule	decreased risk for higher scores	–	Morfeld et al. (2016)
Asian elephant (*Elephas maximus*) *c*	diversity in feeding methods	increased risk for higher scores	–	Morfeld et al. (2016)
Asian elephant (*Elephas maximus*) *c*	duration of musth	positive	–	Somgird et al. (2016)

Table 4. Modifications made to the original body condition scoring protocols (Wemmer et al. 2006, Fernando et al. 2009, Morfeld et al. 2014, Wijeyamohan et al. 2014) for their application in the test of the different scoring approaches performed in the present study.

Approach of the scoring system	Author of original protocol	Species	Modification for application in test	Potential alterations of the outcomes
Composite	Wemmer et al. (2006)	Asian elephant (*Elephas maximus*)	Flank area, which was weighted by one point only in the original paper and showed least correlation with subcutaneous fat measurements according to Morfeld et al. (2014), was excluded. Thus the range of the score was reduced from 0–11 to 0–10.	A higher reliability in the scores might be reached.
Algorithm	Morfeld et al. (2014)	African elephant (*Loxodonta africana*)	Addition of score 0 for extremely emaciated elephants. Moreover the five categories were subdivided with the stages in between in accordance to Wijeyamohan et al. (2014). Thus the score range was extended from 1–5 to 0–10.	The scores may express a higher differentiation due to the smaller increments. Through the wider score range, inter-scorer consistency may decrease.
Algorithm	Wijeyamohan et al. (2014)	Asian elephant (*Elephas maximus*)	Addition of score 0 for extremely emaciated elephants. Thus the score range was extended from 1–10 to 0–10.	Higher differentiation for elephants in poor condition.
Overview	Fernando et al. (2009)	Asian elephant (*Elephas maximus*)	Combination of the exemplary pictures with the detailed description provided in Morfeld et al. (2014) and Wijeyamohan et al. (2014).	More assistance for unexperienced scorers which may lead to a higher intra- and inter-scorer consistency of the results.
Overview	Morfeld et al. (2014)	African elephant (*Loxodonta africana*)	Addition of score 0 for extremely emaciated elephants. Thus the score range was extended from 1–5 to 0–10. Combination of description with the one provided in Wijeyamohan et al. (2014).	Higher differentiation for elephants in poor condition.
Overview	Wijeyamohan et al. (2014)	Asian elephant (*Elephas maximus*)	Addition of score 0 for extremely emaciated elephants. Thus the score range was extended from 1–10 to 0–10. Combination of description with the one provided in Morfeld et al. (2014).	Higher differentiation for elephants in poor condition.

prominence. In comparison, the visibility of the backbone determines whether an elephant with unrecognisable ribs is given a BCS of 4 or 5.

Overview body condition scoring

Fernando et al. (2009), Morfeld et al. (2014) and Wijeyamohan et al. (2014) suggest systems basing on example photographs and corresponding descriptions for each score. Doing so, the typically assessed body areas are evaluated, but not scored individually. Thus, no defined prioritisation exists between them.

Neither Morfeld et al. (2014) nor Wijeyamohan et al. (2014) compare BCS obtained following a flow chart algorithm and BCS obtained by overview scoring. Scoring black rhinoceroses, Reuter and Adcock (1998) reported the best inter-observer repeatability when the scores given to the various body regions were combined. In contrast, Isensee et al. (2014) found in dairy cattle that results showed a stronger correlation to fat measurements if body

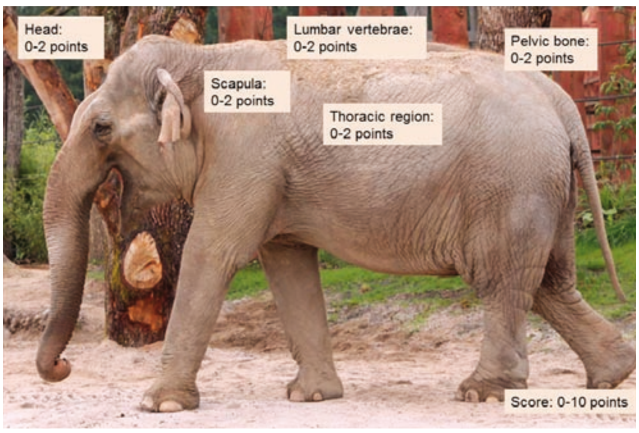

Figure 1. Composite body condition scoring in elephants modified according to Wemmer et al. (2006).

regions were not scored individually, but a "general impression" overview scoring was applied. Obviously, the presentation of example scores together with a minimal description will be more practical under field conditions, due to its simplicity. Moreover, it requires less expertise from the evaluator, as intended especially by Fernando et al. (2009).

Testing the different approaches to visual BCS

Method

In order to demonstrate differences between the various visual scoring approaches, a set of 30 lateral photographs of 30 different individual European zoo elephants, 15 African (*Loxodonta africana*) and 15 Asian (*Elephas maximus*), was given to 18 individual veterinary students (3rd and 4th year students from the universities of Bern and Zurich) with no experience in elephant BCS scoring. The picture sets for both species were balanced regarding gender distribution, but not regarding score ranges. The latter was assumed to be practical with respect to the existing literature, where comparable protocols have been applied for Asian and African elephants (Morfeld et al. 2014, 2016). A self-explanatory instruction sheet for each scoring approach was supplied to the students together with the test documents. No further instructions were given. Each student scored all 30 elephants, 10 with the overview method (Fernando et al. 2009; Morfeld et al. 2014, Wijeyamohan et al. 2014), 10 with the composite method (Wemmer et al. 2006) and 10 with the algorithm method (Morfeld et al. 2014; Wijeyamohan et al. 2014), i.e. no student scored the same individual twice. The three scoring systems were modified so that all yielded the same number of scores (0–10). In doing so, we kept the number of modifications to a minimum (listed in Table 4). The modified protocols are depicted as they were used in the instruction sheet (Fig. 1–3). Under the assumption that there is no evidence for a difference in body fat deposition between elephant species, a single protocol was applied for Asian

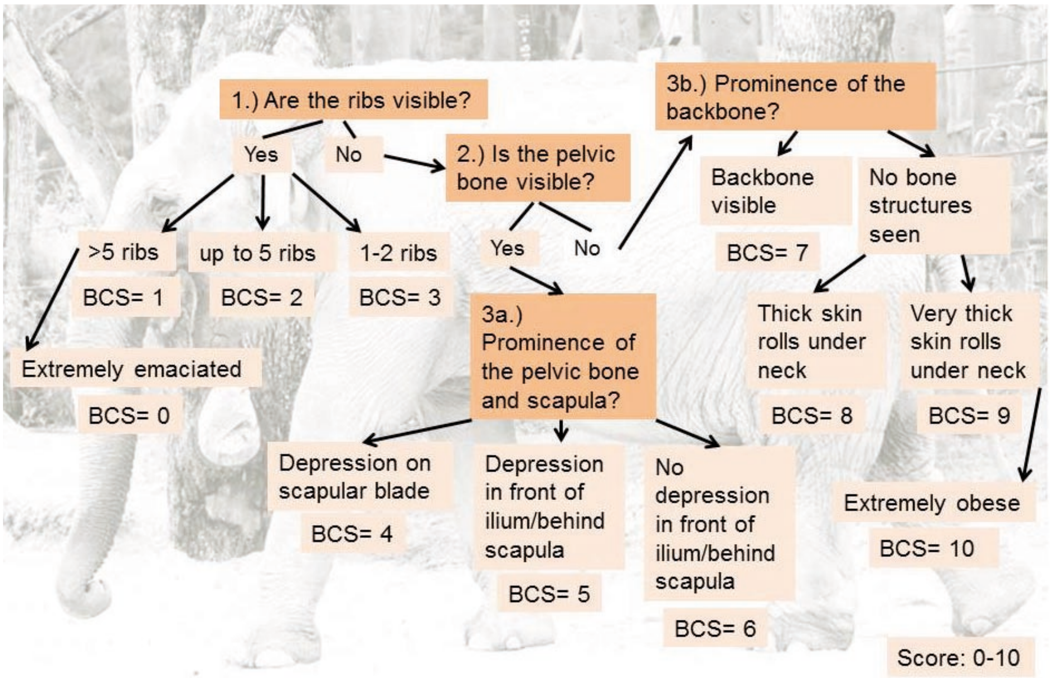

Figure 2. Algorithm body condition scoring in elephants modified according to Morfeld et al. (2014) and Wijeyamohan et al. (2014).

and African elephants. Test duration was limited to approximately 15 minutes per 10 photographs, with breaks of variable duration between the scoring sessions.

Differences between scoring methods were analysed with repeated measurements ANOVA (using the individual elephants as the basis of comparison, with the three methods the repeated measures for each animal) with a Sidak post hoc test. Additionally, for each scoring method, all 30 elephants were compared using ANOVA and Dunnet's T post hoc test (due to inequal variances), and the number of individual pairs with significant differences were counted (out of all 435 possible pairs). Finally, a General Linear Model (GLM) was performed with BCS as the dependent variable, student as a random factor, and both method and elephant species as fixed factors; normal distribution of residuals was confirmed by Kolgomorov–Smirnov test. The level of significance was set to 0.05.

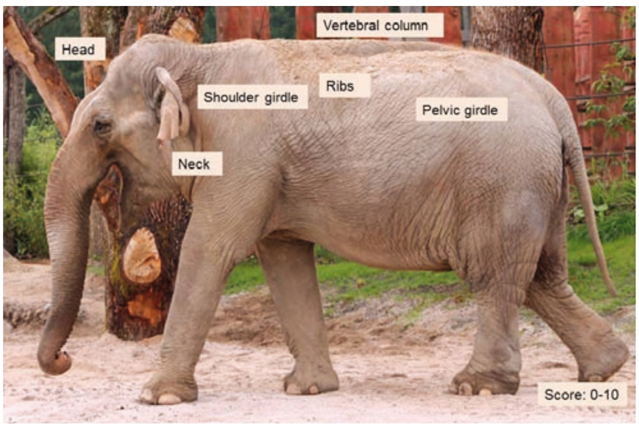

Figure 3. Overview body condition scoring in elephants modified according to Fernando et al. (2009), Morfeld et al. (2014) and Wijeyamohan et al. (2014).

Results

The algorithm method resulted in 26 significantly different pairs, the composite method in 55 significantly different pairs, and the overview method in 74 significantly different pairs. Across all individuals, composite scoring resulted in the largest range of mean and median BCS for individual animals (mean 2.7–9.5), followed by overview scoring (3.0–8.8), and algorithm scoring had the lowest range of scores (3.0–8.0) (Fig. 4). There was more inter-observer variation with the composite method (Table 5). Concerning the minimum score, a difference between the approaches was detectable, with composite scoring showing a significantly lower value than the other systems (Table 5). There were no significant differences in the overall mean, median and maximum scores between methods (Table 5). In the GLM, the random factor "student" was significant ($F_{20,606}$ = 2.405, P = 0.001), indicating systematic differences between the individual students; method was not significant ($F_{2,606}$ = 1.335, P = 0.264); and there was a significant difference between the two elephant species ($F_{1,606}$ = 116.821, P < 0.001, African: 5.2 ±1.8, range 1–10; vs Asian: 6.7 ±1.8, range 3–10), reflecting the fact that we had not aimed to balance BCS scores across species when selecting our example pictures.

Discussion

Our results show significantly higher inter-observer repeatability for the overview and algorithm approaches, while the composite protocol leads to more variability between scorers. A possible explanation for the decreased inter-observer repeatability of the composite approach might be the segmented mode of this system. While the other protocols consider the whole elephant, the composite method clearly subdivides the animal into separate regions. Reported results from a similar comparison in dairy cattle corroborate this hypothesis (Isensee et al. 2014). Moreover, the composite system weighs head and scapula equally with the remaining regions. In contrast, the algorithm and overview approach put the main emphasis on the lumbar region, the backbone and the

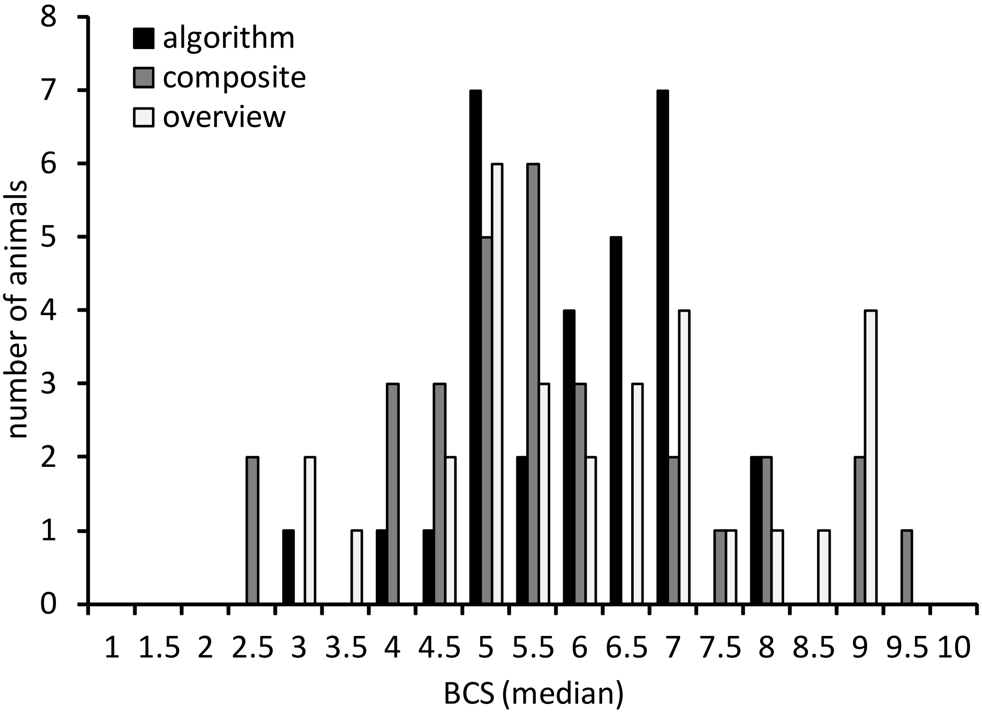

Figure 4. Differentiation of individual zoo elephant body condition scores (BCS) (median) by three different scoring approaches.

ribs, with minimal consideration of the head and shoulder areas. With respect to the most current species-specific publications, the former body regions can be assumed to be the critical ones for an elephant's condition (Morfeld et al. 2014, 2016). Our results are in contrast to those of Reuter and Adcock (1998), who reported the most repeatable mean scores for black rhinos by the composite method. This discrepancy might be caused by the inherent differences in the corresponding protocols. While we used a system modified from Wemmer et al. (2006), containing five body regions with three gradations in each, Reuter and Adcock (1998) scored seven body regions with five gradations each. This might have led to more reliable results in the rhino study. Thus, it can be speculated that the composite approach in elephants could be improved by extending the number of scored body regions and/or the number of increments. In doing so, the intended simplicity and practicability of a scoring system should not be forgotten.

Whether our findings are representative for a variety of people (e.g. veterinarians, elephant handlers) and other animal species needs to be tested in further studies. Moreover, our investigation explicitly used the lateral view of an elephant. It is possible that the evaluation of various views could lead to differing results. The reported difference in minimum scores between the methods indicates an inconsistent application of the categories in elephants of reduced condition. For animals in reduced condition, overview and algorithm approaches provided a higher consistency in scores compared to the composite method. This finding may indicate that refined scoring criteria for individuals of low body condition should be emphasised in the development of future composite-based systems. The overall consistency of mean, median and maximum scores between methods may indicate that overall results may be comparable between studies, independent of the scoring approach applied. Additionally, the overall consistency of these results can be interpreted as confirmation of the practicability and reliability of the visual scoring approach in general. Based on our limited findings, the overview scoring approach can be recommended as a reliable method with a high level of differentiation in the evaluation of elephant body condition.

Table 5. Mean (±SD) body condition scoring (BCS) means, medians, minima, maxima, and ranges for 30 zoo elephants scored by three different methods by six scorers per animal. Different superscripts (a, b) within a row indicate significant differences between the scoring methods.

	Overview	Composite	Algorithm	P-value (method)
Mean	6.1 ±1.6	5.2 ±1.7	5.9 ±1.1	0.208
Median	6.2 ±1.7	5.7 ±1.8	6.0 ±1.2	0.135
Minimum	4.6 ±1.7[a]	3.9 ±1.9[b]	4.5 ±1.1[ab]	0.020
Maximum	7.5 ±1.6	7.7 ±1.6	7.4 ±1.4	0.165
Range	2.8 ±1.0[a]	3.8 ±1.4[b]	2.9 ±1.0[a]	0.002

Practical impact of visual BCS on zoo animal husbandry

BCS have been found to correlate with various individual, environmental and husbandry-related factors (Table 3); such studies underline the usefulness of BCS.

One important question in applying BCS is at what intervals the scoring should be done.

The current literature provides few guidelines on this. In geese, Clausen et al. (2015) found that poor condition after harsh winters was detectable over a timeframe of at most two months. Investigating the diet of Asian and African elephants in Brazilian zoos, Carneiro et al. (2015) demonstrated visually observable effects on their body condition three months after dietary reduction. In their report on free-ranging African elephant bulls suffering from injuries, Ganswindt et al. (2010) recognised a decrease in their physical condition over two months. Thus, an interval of 2–3 months seems reasonable for body condition scoring in elephants. Smaller species should theoretically be scored more frequently due to their increased metabolism. In this respect, the 2–3 month interval for elephants should be considered the maximum time interval. This recommendation is assumed to be adequate for both Asian and African elephants; no evidence concerning their potentially different subcutaneous fat deposition has been reported yet. Morfeld et al. (2016) demonstrated the reliability of a comparable BCS system for the Asian as well as the African species.

In farm animals, efforts are directed towards including visual BCS systems in automated techniques for continuous animal status surveillance (Bewley et al. 2008; Azzaro et al. 2011; Bauer et al. 2012). In this process, strictly standardised photographs are required that facilitate the BCS evaluation by computer programs, thus reducing the method´s subjectivity and personnel effort (Ferguson et al. 2006; Bewley et al. 2008). Although no practically applicable automated systems are available yet, promising preliminary results have been reported (Negretti et al. 2008; Bauer et al. 2012; Bercovich et al. 2013). In zoo animal species with their significantly wider anatomical and morphological variability, such automated systems may be difficult to develop. However, using established BCS procedures on a regular basis with storage of standardised photographs, digital archives may be set up to allow monitoring individual body condition development over time. Digital photography could thus become part of an individual zoo animal's life history, completing health and reproductive records.

To conclude, visual body condition scoring systems can be considered a helpful tool in weight management of zoo animal species. This has been shown especially in rhinos and elephants, where weighing is often impractical. Regular standardised pictorial documentation of individuals with subsequent development of a corresponding digital archive is strongly recommended. This approach may provide zoos with a simple, practical and reliable monitoring tool for diet and husbandry concepts of their animals, including retrospective assessments. Regular BCS monitoring may also serve as an early warning system in health monitoring of wild and zoo animals. With respect to the results of the current study, scoring in elephants may be best completed using overview and/or algorithm methods.

Acknowledgements

The participation and/or support of Monika Bochmann, Vera Burkard, Lea Carisch, Irina Clavadetscher, Nina Engel, Jacob Erb, Nicole Kälin, Ramona Keiser, Rahel Hufenus, Michaela Hutter, Nora Lüdi, Louise Martin, Tegan Melliger, Simone Rusterholz, Diana Sainger, Thomas Schmid, Katja Schönbächler, Gian-Luca Steger, Nicole von Niederhäusern, Patricia Kälin-Kienberger is gratefully acknowledged.

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